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Health Science

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Health Science

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1 The cellular structure of living organisms

Plants and animals

CHARACTERISTICS OF LIVING THINGS

1 **Feeding.** All living things need food; without food they die.
2 **Breathing.** Living things use air for breathing.
3 **Excretion.** The end products of feeding and respiration are removed from all living things; this is by excretion.
4 **Movement and growth.** All living things grow as they become older. Many living things can move as well as grow.
5 **Reproduction.** All living things produce another generation; this is reproduction.
6 **Irritability.** All living things show a response to their surroundings; irritability is the response to an environment.

THE BASIC DIFFERENCES BETWEEN PLANTS AND ANIMALS

Plants	Animals
1 Usually remain in one place.	1 Move in search of food.
2 Make their own food from simple substances in the air and in the soil.	2 Do not make their own food. They eat readymade food obtained from plants or other animals.
3 Usually contain a green substance, chlorophyll, used in making plant food.	3 Do not contain chlorophyll.
4 Show slow responses to their environment.	4 Show quick responses to their environment.

THE SIMILARITIES BETWEEN PLANTS AND ANIMALS

Both plants and animals *respire*, and *excrete*. They both *grow* with increase in age; they both *reproduce*.

ENERGY

Energy gives the ability to do work. There are different kinds of energy: mechanical energy; heat energy; light energy; electrical energy; chemical energy. A living thing which is moving uses mechanical energy; other life processes also require energy. Food contains chemical energy, and during respiration energy is released from the food for use by the living organism. The energy released from food is (a) partly used to form heat to keep the body warm; (b) partly changed to mechanical energy to give movement; and (c) partly used to provide chemical energy to form new chemical substances used in life processes.

Cells

CELLULAR STRUCTURE OF LIVING THINGS

The living substance of a plant or animal is made up from tiny compartments, called **cells**. The cells can only be seen by using a microscope. All cells consist of (a) a nucleus, which controls the cell; (b) protoplasm, which is the basis of living things; and (c) a protective covering to the cell, called a **membrane**.

Protoplasm. This substance is a greyish coloured liquefied jelly, which is about four-fifths water. It is a mixture of different compounds. The compounds are continually taking part in chemical changes, using chemical energy for the changes. This complicated process of chemical change is called 'living', and when the changes no longer take place, death occurs.

Reproduction in cells. The nucleus of a cell divides in two, and the cell becomes oval in shape. The cell then forms two halves joined by a narrow bridge of protoplasm, with a nucleus in each half. The bridge of protoplasm then breaks, forming two **daughter** cells, each smaller than the parent cell. The daughter cells then grow to the size of their parent.

TYPES OF CELLS

Plant cells and animal cells have similarities and differences (table below). The higher plants and animals have developed different types of cells used for special purposes; this is called cell specialisation, and is explained in the section on the human body.

A COMPARISON OF PLANT AND ANIMAL CELLS

Plant cells	Animal cells
1 Possess a nucleus, and protoplasm. 2 Have a cell membrane. 3 Energy released from dissolved food during tissue respiration. 4 Waste products excreted.	1 Possess a nucleus and protoplasm. 2 Have a cell membrane. 3 Energy released from dissolved food during tissue respiration. 4 Waste products excreted.
1 Tend to be regularly shaped. 2 Possess a cell wall round cell membrane. 3 Have large vacuoles. 4 May have chlorophyll in chloroplasts.	1 Usually irregularly shaped. 2 Do not possess a cell wall. 3 Do not have vacuoles. 4 Do not have chlorophyll.

Yeast

UNICELLULAR ORGANISMS

Yeast is an organism consisting of one cell. The single cell carries out all the life processes of *feeding, respiration, excretion, growth, reproduction* and *irritability*. The cell consists of a nucleus, protoplasm, cell membrane and a thin cell wall. It is a useful example of a single cell for a simple study of living processes.

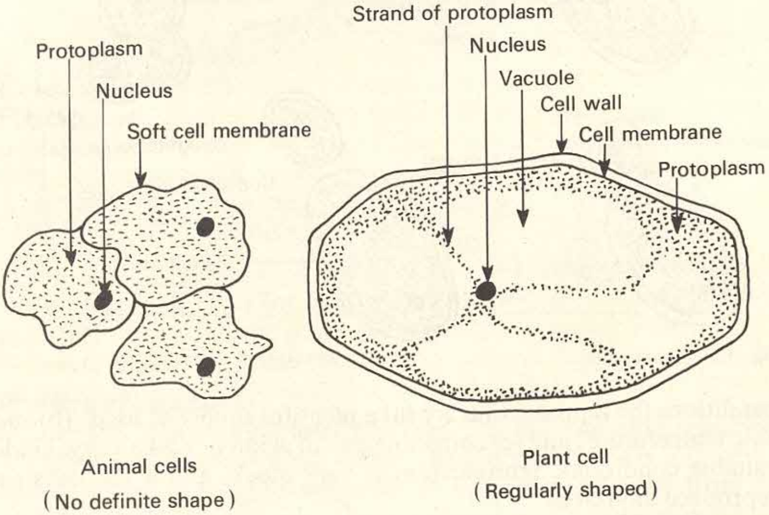


fig. 1.1 Plant and animal cells

NUTRITION IN YEASTS

The process of obtaining and using food is called **nutrition.** Yeast is a plant, but it possesses no chlorophyll, so it must use ready-made food. *External digestion*. The yeast releases **enzymes** (see page 13) which break down certain foods to glucose. The yeast must have water present for this chemical reaction to take place. The glucose is absorbed by the cell. Tissue respiration releases energy from the glucose. Respiration usually releases energy by the action of **oxygen** on glucose; this is called **aerobic respiration.** Yeast does not use air (or oxygen) for respiration; it uses an enzyme, called **zymase**, to release energy.

$$\text{glucose} \xrightarrow{\text{zymase}} \text{alcohol} + \text{carbon dioxide} \ (+ \text{energy})$$

EXCRETION IN YEASTS

The end products of tissue respiration, alcohol and carbon dioxide, are excreted. The nutrition processes of yeast cause fermentation, as alcohol is produced.

REPRODUCTION IN YEASTS

When conditions are suitable, a yeast cell forms a bud. The bud grows, and detaches itself to form a daughter cell. Chains of yeast cells can be formed if a daughter cell forms a bud before detaching itself. Suitable conditions for reproduction are (a) a plentiful supply of food; (b) suitable temperature; and (c) correct degree of acidity or alkalinity. Under suitable conditions, reproduction is very quick, and a few cells can reproduce thousands.

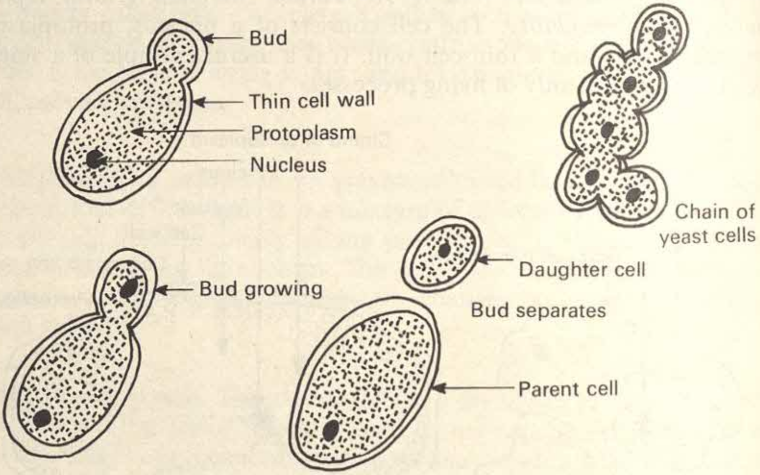


fig. 1.2 Yeast cells

Spore formation. When conditions are unfavourable, a thick protective covering forms round a yeast cell; all activity stops, but the cell does not die. A spore has been formed which will live through adverse conditions. Under suitable conditions, the spore case breaks open, and the cell feeds and reproduces.

REACTION TO ENVIRONMENT

If yeast is heated beyond a certain temperature, the cells are killed. If the concentration of alcohol reaches 15% in a solution, the cells are killed also. If the surroundings dry up, spores are formed.

Uses of yeast. There are many different types of yeast, used to ferment different foods. Each yeast produces different enzymes to break down the food to glucose; all yeasts produce zymase to break down glucose to alcohol and carbon dioxide. Baker's yeast acts on starch in bread, and the carbon dioxide causes the bread to 'rise'. Wines and beer are made by yeasts.

PROTOZOA

A protozoon is a unicellular animal. *Entamoeba* is an example of a protozoon; it lives in the intestines of man and causes the disease of **amoebic dysentery.** The infected person is called a **host.**

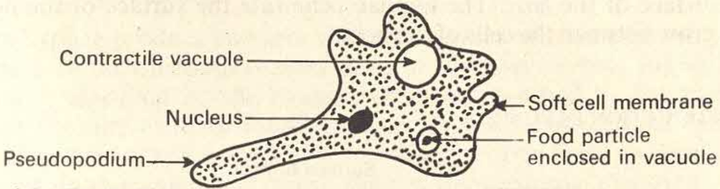


fig. 1.3 a Entamoeba cell

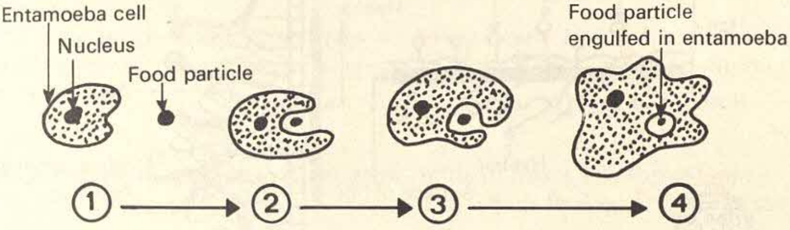


fig. 1.3 b Entamoeba and movement

Structure of entamoeba

The cell size is that of a printed full stop. The cell looks like a piece of grey jelly, and has no definite shape. The cell membrane is soft, which allows the cell to form *pseudopodia*, by protoplasm flowing from the cell into the pseudopodium. The pseudopodia engulf food particles, and also produce movement from place to place.

NUTRITION IN ENTAMOEBA

A food **vacuole** is formed round a food particle; digestive juices make the food soluble, and the cell absorbs the dissolved food from the vacuole. Some soluble food is absorbed directly from the intestines of the host. Respiration in the protoplasm releases energy for life processes, and forms waste products.

Excretion. Waste products and surplus water collect in a **contractile vacuole;** the vacuole contracts and expels the contents out of the cell. The excreted substances irritate the intestines, causing inflammation leading to abdominal pains and the frequent passing of stools. The stools contain blood and mucus.

REPRODUCTION OF ENTAMOEBA

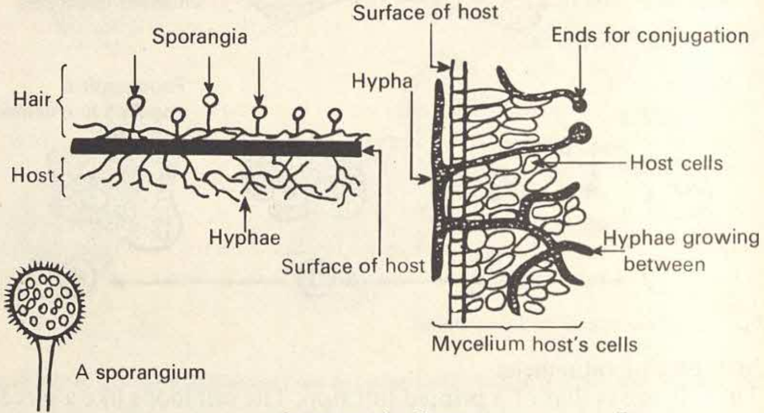
Entamoeba leaves the intestines with the **faeces;** it forms a **cyst,** which is similar to a spore. The cyst enters a new *host*, breaks open, and reproduces by division of one cell to form two daughter cells.

Fungi

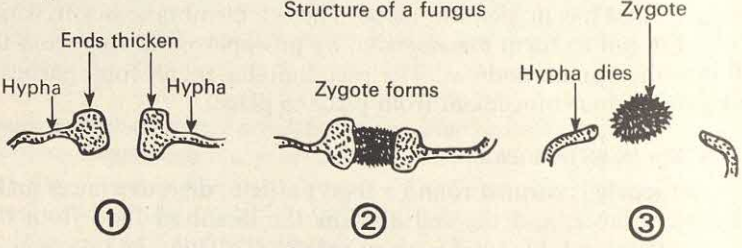
Structure of fungi

A fungus consists of delicate threads, called **hyphae,** which grow on the surface of the *host*. The hyphae penetrate the surface of the host and grow between the cells of the host.

REPRODUCTION IN FUNGI



Structure of a fungus



Conjugation in fungi

fig. 1.4 Fungi

In favourable conditions, the hyphae produce sporangia. Each is shaped like a little ball at the end of a stalk. When the sporangia are ripe, they burst and scatter spores into the air. If the spores settle in suitable conditions, hyphae grow from the spores, and new plants are formed.

Conjugation. Some fungi can reproduce by conjugation. Two hyphae, from different plants, or the same plant, approach each other; the ends of the hyphae thicken and form round knobs. Between the two knobs, a **zygote** is formed; the zygote is protected by a thick, spiky coat, and it can withstand adverse conditions. When conditions are suitable, the zygote coat splits open, and a new plant grows from it. The zygote is a *resting* stage of a fungus.

NUTRITION IN FUNGI

The hyphae produce enzymes which decompose the **substrate** (i.e. the substance on which an enzyme acts, or the host's cells); the soluble food is absorbed by the hyphae. Oxygen, absorbed by the hyphae from the air, oxidizes food in tissue respiration to release energy. Hyphae cannot penetrate a host too deeply as they need oxygen from the air. In this nutrition process, fungi employ external digestion.

Parastic fungi. These fungi grow on living hosts. Examples: *pythium*, which grows on seedlings; *ringworm, tinea*, which grow on human beings.

Saprophytic fungi. These fungi grow on dead hosts. Examples: *mucor*, which grows on stale bread; *mushrooms*, which feed on humus in the soil.

FUNGI AS AGENTS OF CHANGE, DECAY AND DISEASE

Fungi are plants which do not possess chlorophyll. Yeast is a unicellular fungus; parasitic fungi are usually called **mildews**; saprophytic fungi are usually called **moulds.** Edible fungi (mushrooms) possess large sporangia, the visible part of the mushroom which is eaten. The mass of hyphae is called the **mycelium.**

Decay. Saprophytic fungi decompose organic material, and are useful as they help to remove dead plants and animals; the process is completed by bacteria.

Disease. Parasitic fungi produce excretory products in living hosts; the products interfere with the host's life processes and cause disease. Maize rust and potato blight are caused by fungi. Ringworm, athlete's foot, and dhobi itch are fungal diseases in man.

Fermentation. Yeasts produce fermentation.

Change. The moulds on cheese, which ripen it, and the fungi which take part in pickling processes, are examples of useful change produced by saprophytic fungi.

The human body

SPECIALISATION OF CELLS

Different types of cells are shown in fig. 1.5, and the organisation of cells in the body is given in the table below.

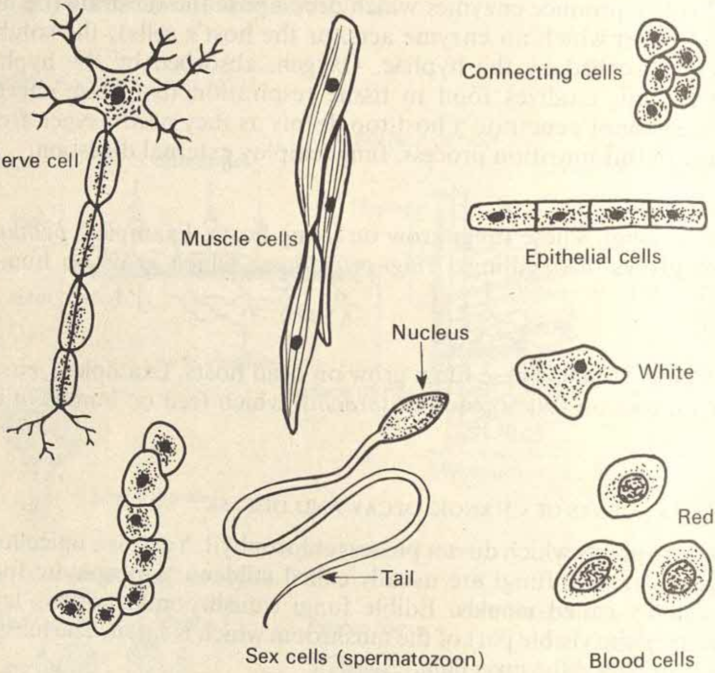


fig. 1.5 Different types of cells

ORGANISATION OF CELLS

Description	Structure
Tissue	A group of cells, each a specialised cell with the same function, e.g. muscular tissue.
Organ	Two or more tissues carrying out the same function, e.g. the stomach, the lungs.
System	Two or more organs carrying out the same function, e.g. the circulatory system.
Organism	All the systems working together.

2 The functions of the healthy body

The human organism

Man is a living organism and has the characteristics of a living animal. Man has complex systems of organs, which are composed of specialised cells, and each system plays its part in the life processes of the whole organism.

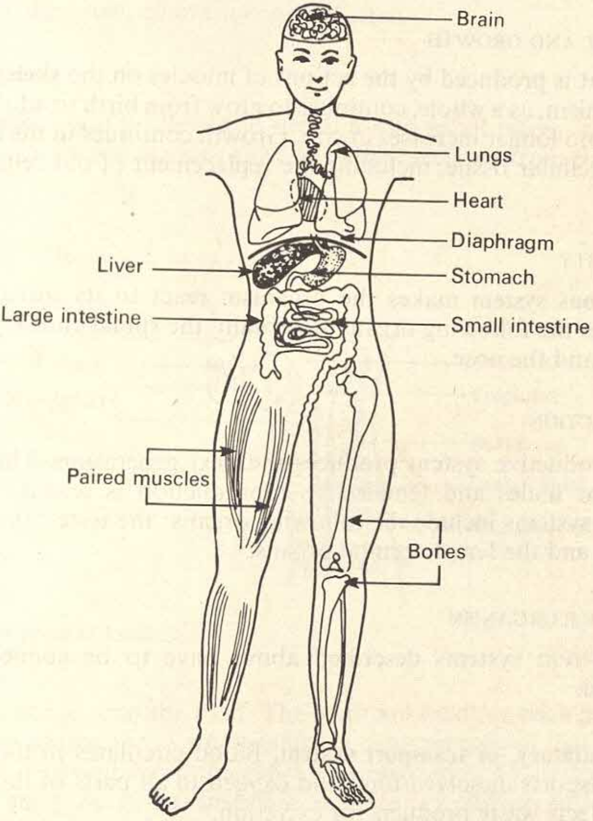


fig. 2.1 The human body

FEEDING

The **alimentary canal** is the system which converts food into soluble substances ready for the release of energy by internal respiration. The alimentary canal includes the following organs: the stomach, the duodenum, the small intestine, and the large intestine.

BREATHING

The **respiratory system** provides the oxygen required for internal respiration. The main organ of respiration is the lung. Man has two lungs.

EXCRETION

The **excretory system** gets rid of the waste products of internal respiration. It includes the following organs: the kidneys, and the lungs (which excrete carbon dioxide.)

MOVEMENT AND GROWTH

Movement is produced by the actions of muscles on the **skeleton**. The organism, as a whole, continues to grow from birth to adolescence, and then no longer increases in size. Growth continues in the development of cellular tissue, including the replacement of old cells by new cells.

IRRITABILITY

The **nervous system** makes the organism react to its surroundings. It includes the following organs: the brain, the spinal chord, the eyes, the ears, and the nose.

REPRODUCTION

The reproductive system produces the next generation. This system differs for males and females, as reproduction is sexual. The two different systems include the following organs: the testes, the ovaries, the male and the female genital organs.

THE WHOLE ORGANISM

The different systems described above have to be connected and protected.

The circulatory, or transport system. Blood circulates in this system, and transports dissolved food and oxygen to all parts of the body. It then collects waste products for excretion.

The skin. This provides a protective covering for the whole organism, and also protects the different systems from heat changes in the surroundings.

The human body. The relative positions of some of the more important organs are shown in fig. 2.1. Each system in the body is interdependent on the other systems for its correct functioning.

Nutrition in the human body

FOOD

The word **food** is used to mean the actual substance eaten, i.e. rice, meat, cabbage, etc. The word, **foodstuff**, means the chemical substance used by the organism, e.g. types of carbohydrates, types of protein, etc. Nutrition is the process in which foodstuffs are extracted from foods, and then made into simpler, soluble substances which can be used by the cells in the body. The process takes place in four stages: *ingestion, digestion, absorption, assimilation.*

INGESTION

The mouth. Food is chewed to break it into small pieces, so that the digestive juices can act more easily. **Saliva**, secreted from the salivary glands, is mixed with the food. The teeth are used for both processes, assisted by the tongue. A small *bolus* (i.e. a round ball) of food is formed, which is passed down the **gullet** (or **oesophagus**) by contraction of muscles lining the gullet. **Ingestion** includes the passage of food into the mouth, through the throat (or pharynx), down the gullet into the stomach.

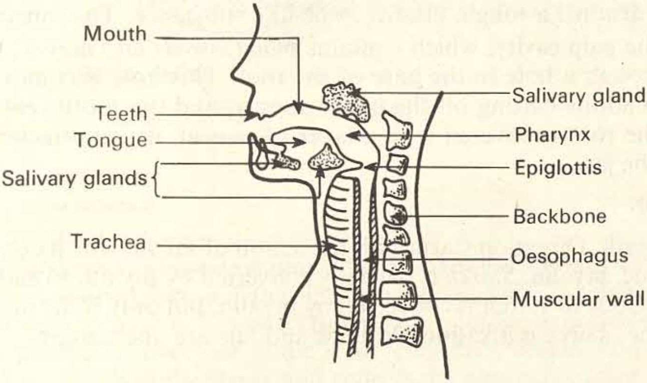


fig. 2.2 Ingestion of food

The teeth. Humans have two sets of teeth: (a) milk teeth which form at $2\frac{1}{2}$ years, and at 6 years, are displaced by (b) permanent teeth. There are 32 permanent teeth; 8 incisors, 4 canine teeth, and 20 molars. **Incisors** are used for *biting* food; **canines** are used for *tearing* meat; **molars** are used for *crushing* and *grinding* food into small particles.

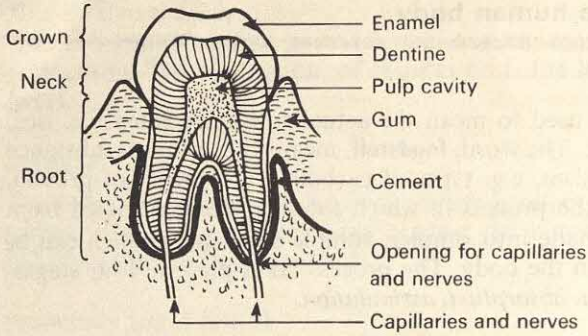


fig. 2.3 Structure of a tooth

Structure of a tooth. A tooth is divided into three regions: the **crown**, the part that projects from the gums; the **root**, the part in the gums; and the **neck** that joins the crown and the root. The crown is covered with **enamel**, the hardest substance in the body. The main bulk of the tooth is **dentine**, a tough, elastic, bone-like substance. The innermost part is the **pulp cavity**, which contains *blood vessels* and *nerves*; these enter through a hole in the base of the root. This hole becomes very small, in adults cutting off the blood supply, and the tooth ceases to grow. The root is covered with a layer of **cement**, which attaches the root to the jaw.

DIGESTION

In the mouth. Digestion starts with the action of saliva, which contains an enzyme, **ptyalin**. *Starch* is partially converted by ptyalin to **maltose**, a sugar. Cooked starch is converted by ptyalin, but only if the mixture is alkaline; saliva is alkaline. Proteins and fats are unchanged.

In the stomach. Food enters the stomach in the middle, and slowly extends to the walls. The stomach wall is muscular, and its action mixes the food, and moves it to the **pyloric orifice.** This orifice is closed by a powerful muscle, which opens periodically to pass the stomach contents to the duodenum.

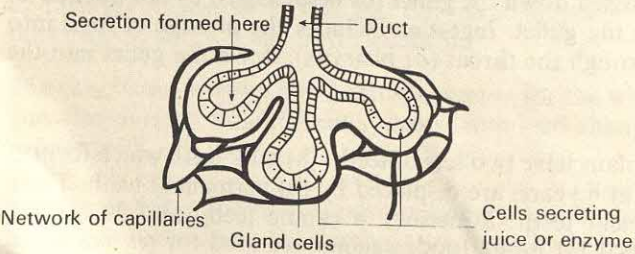


fig. 2.4 A secretory gland

Glands in the wall of the stomach secrete **gastric juice**, which is acid, and contains the enzymes **pepsin** and **rennin**. The acid (hydrochloric acid) neutralises the alkaline saliva, and stops the action of ptyalin. Pepsin converts some proteins to **peptones**. Young humans secrete **an** enzyme, **rennin**, which clots milk, separating the proteins from the fats in it.

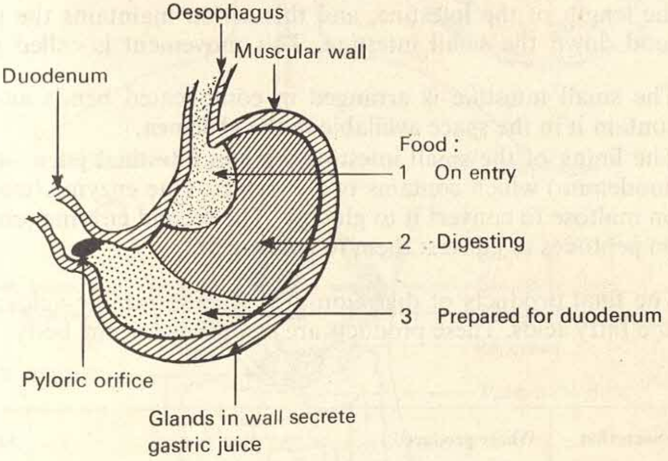


fig. 2.5 The stomach

In the duodenum. The duodenum is the first part of the small intestine, and it is shaped like a letter U, curving round the **pancreas**. The pancreas is a pink coloured gland which secretes a digestive juice, called **pancreatic juice**; its shape is an irregular triangle. A duct runs the whole length of the gland, and collects the pancreatic juice secreted by glandular cells. The **pancreatic duct** is joined by the **bile duct**, just before the duct leads into the duodenum. The bile duct carries **bile** from the **gall bladder** in the liver.

Bile is an alkaline liquid containing bile salts; it neutralizes the acid products of digestion in the stomach, and stops the action of pepsin. The **bile salts** reduce the surface tensions of the liquids and *emulsify* fats, so that the fats can be acted upon by the enzymes in pancreatic juice. The enzymes in pancreatic juice need an alkaline liquid for their reaction. Bile salts also colour the faeces.

Pancreatic juice contains three enzymes. One enzyme (amylase) acts on any unconverted starch and changes it to maltose. A second enzyme (trypsin) continues the digestion of proteins to peptones. A third enzyme (lipase) splits fats into **glycerol** and **fatty acids**.

In the small intestine. The small intestine is a long thin muscular tube beginning at the stomach, and leading to the large intestine. It has a *mucous* lining, which is arranged in folds to prevent food passing too quickly, and to provide a larger absorbing surface. The lining of the small intestine is covered in **villi**, small finger-like projections, which take part in the assimilation of food. The muscular wall of the intestine contracts and pushes food before it. A wave of contraction passes down the length of the intestine, and this action maintains the passage of food down the small intestine. This movement is called **peristalsis**.

The small intestine is arranged in complicated bends and folds to contain it in the space available in the **abdomen**.
The lining of the small intestine secretes **intestinal juice** (so does the duodenum) which contains two enzymes. One enzyme (maltase) acts on maltose to convert it to glucose. The second enzyme (erepsin) acts on peptones to convert them to **amino-acids**.

The final products of digestion are: glucose; amino-acids; glycerol; and fatty acids. These products are *assimilated* by the body.

Secretion	**Where produced**	**Reaction**	**Enzyme**
Saliva	Salivary glands	Some starch → maltose	Ptyalin
Gastric juice	Stomach	Proteins → peptones Milk clotted	Pepsin Rennin
Pancreatic juice	Pancreas	Starch → maltose Proteins → peptones Fats → glycerol + fatty acids	(Amylase) (Trypsin) (Lipase)
Bile	Liver	Fats emulsified	None
Intestinal juice	Small intestine	Maltose → glucose Peptones → amino-acids	Maltase Erepsin

THE ALIMENTARY CANAL

The alimentary canal starts at the mouth, includes the pharynx, stomach and small intestine. The small intestine leads into the **caecum**, a blind pouch, to which is attached the **appendix**. The large intestine commences at the caecum. Leading from the caecum is the **colon**, a wide muscular tube, with a beaded appearance. There are no villi in the large intestine. Peristalsis is slow in the colon.

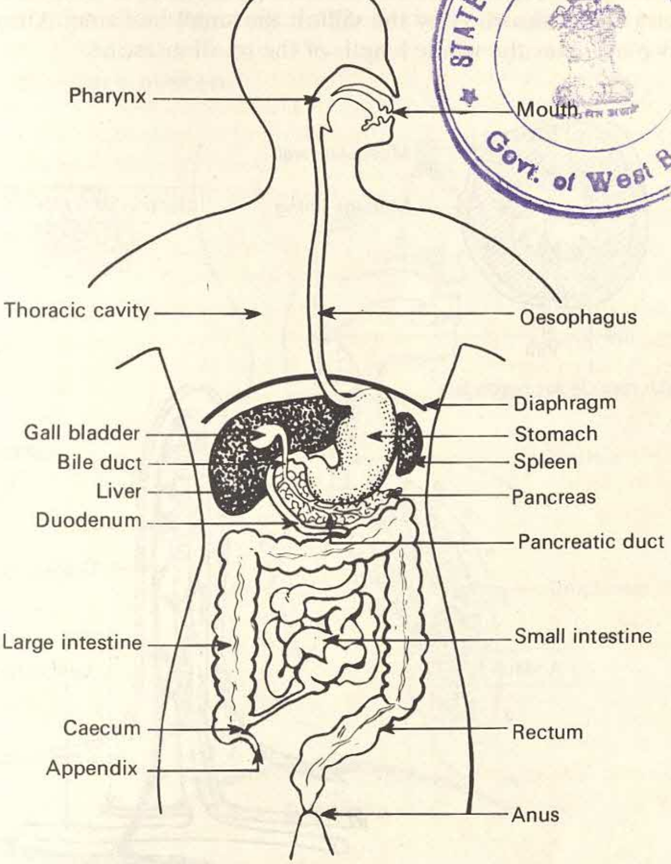


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fig. 2.6 An outline of the alimentary canal

The rectum is the last part of the alimentary canal, and in it faeces are stored before voiding. When the rectum is full, the faeces are passed through the **anus**, a short tube with a powerful muscle. The intestines are supported by thin folds of connective tissue called mesenteries; these tissues carry blood vessels connected to the intestines.

No digestion takes place in the large intestine. The contents of the small intestine are liquid, and as they pass through the colon water is absorbed through the lining of the colon; the contents finally become solid faeces, and are passed into the rectum. Organic salts are also absorbed in the colon. Bacteria in the colon decompose any undigested food, and convert it to faeces. The muscles of the anus are under control of the will, and open when faeces are **voided**.

ABSORPTION

The process of digestion converts insoluble foods to soluble substances which can be absorbed by the villi in the small intestine. Absorption takes place over the whole length of the small intestine.

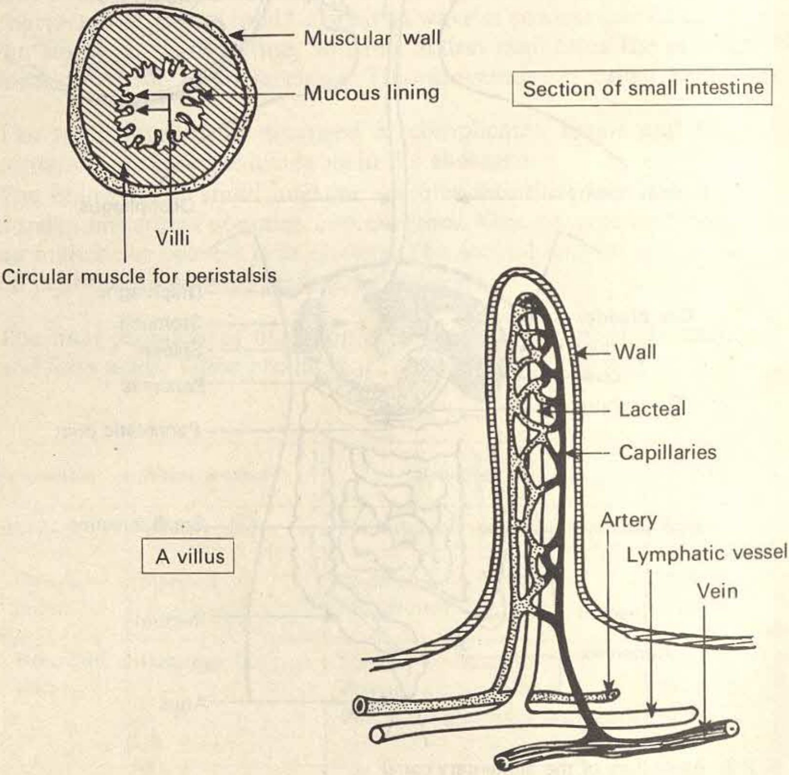

fig. 2.7 A villus and the small intestine

Structure of a villus. A **lacteal,** connected to the *lymphatic system*, is a blind tube in the centre of a villus. It is surrounded by blood capillaries, which are connected to the **mesenteric artery** (delivers blood) and the **hepatic portal vein** (collects blood). The villus is lined with epithelial cells, which select the products of digestion for absorption.

Absorption by a villus. Glucose and amino-acid diffuse through the wall of the villus into the blood in the capillaries, and join the circulatory system. Glycerol and fatty acids diffuse into the lacteal, where they recombine to form fats, and pass into the lymphatic system.

ASSIMILATION

This process takes place in the various cells of the body, and the circulatory system and respiratory system must be considered first.

The respiratory system

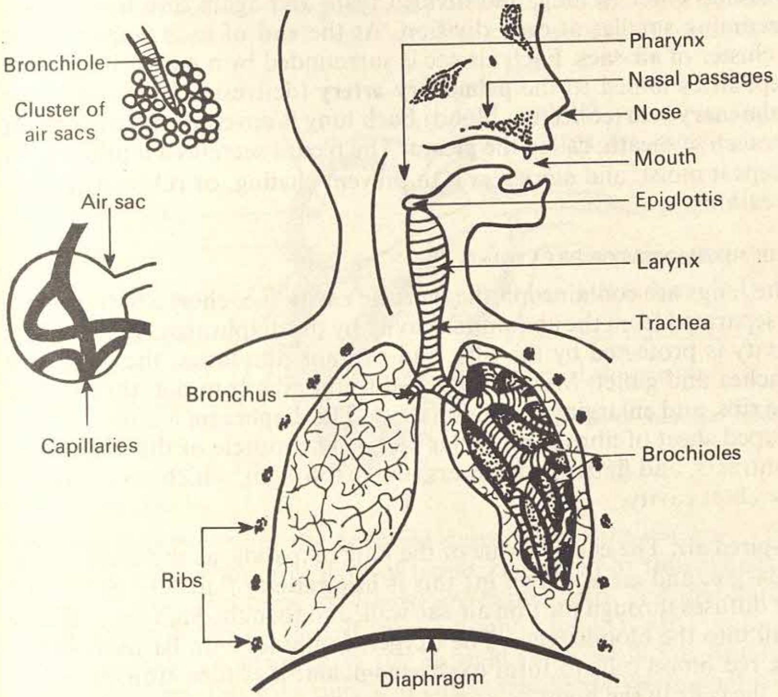

fig. 2.8 The respiratory organs

BREATHING

Oxygen from the air in the atmosphere is *drawn* into the lungs. The air enters the **nose**, and passes through the nasal passages. Bones project into the nasal cavity, forming the nasal passages; these passages are lined with a moist, *mucous membrane*, which removes dust and impurities from the air. Air can also be drawn in through the mouth. Air then passes through the **pharynx** (or throat) to the **glottis**, the opening to the lungs. The glottis is guarded by the **epiglottis**, a flap of tissue which prevents food entering the windpipe. The upper end of the windpipe (or **trachea**) is a swollen box, the **larynx**, across which are stretched the *vocal chords*. Vibration of these chords produces sound. Air passes through the pharynx, glottis, and larynx into the trachea.

The trachea is a long tube lined with hoops of *cartilage*, which keep the tube open however much the neck is bent. At the bottom end, the trachea divides into two **bronchi**, leading to the lungs.

THE LUNGS

The lungs consist of lobes, each containing pink, spongy tissue. A **bronchus** enters a lung, and divides again and again into **bronchioles**, becoming smaller at each division. At the end of each bronchiole is a cluster of **air-sacs**. Each air-sac is surrounded by a network of blood capillaries joined to the **pulmonary artery** (delivering blood) and the **pulmonary vein** (collecting blood) Each lung is covered with an airtight protective sheath, called the **pleura**. The pleura secretes a liquid, which keeps it moist, and *lubricates* it to prevent chafing, or rubbing, during breathing.

THE MECHANISM OF BREATHING

The lungs are contained in the **thoracic cavity** (i.e. chest cavity), which is separated from the abdominal cavity by the diaphragm. The thoracic cavity is protected by the ribs, and contains the lungs, the heart, the trachea and gullet. Muscles attached to the ribs contract, thus raising the ribs, and enlarging the chest cavity. The **diaphragm** is a thin, dome-shaped sheet of fibrous muscular tissue. The muscle of the diaphragm contracts, and flattens, or lowers, the diaphragm, which also expands the chest cavity.

Inspired air. The elastic tissue of the lungs expands, as the chest cavity enlarges, and air is drawn in; this is **inspiration** of air. Oxygen in the air diffuses through the thin air-sac wall, and then through the capillary wall into the bloodstream. The oxygen combines with **haemoglobin** in the red blood cells to form **oxyhaemoglobin**; it is then transported to all the cells in the body.

Respired air. Carbon dioxide in the blood diffuses through·the walls of the capillaries and air-sacs into the air-sacs. The diaphragm and the rib muscles relax, reducing the volume of the chest cavity, and respired air is forced back through the trachea, nose, etc. into the atmosphere. Respired air contains about 4% carbon dioxide, 16% oxygen, and is saturated with water vapour. Atmospheric air contains 20% oxygen, 0·03% carbon dioxide, and less water vapour. The amount of nitrogen remains the same in inspired and respired air.

RESPIRATION

In the cells of the body, the breakdown of complex compounds, such as glucose and fats, by oxidation, releases energy. This release of energy is **respiration** (sometimes called tissue respiration or internal respiration). Breathing is called external respiration. (See the section on assimilation.)

The circulatory system

THE HEART

This organ conists of two thin-walled auricles, and two thick-walled, muscular ventricles. The auricles and ventricles are labelled left and right. The **caval veins** enter the right auricle, and the pulmonary vein enters the left auricle. The **pulmonary artery** leaves the right ventricle and the **aorta** leaves the left ventricle. The right auricle is connected to the right ventricle, and the **tricuspid** valve guards the entrance. The valve is formed from *three* flaps of tissue, connected by thin chords to the heart wall. The flaps (or cusps) are cup-shaped, and maintain a one-way flow of blood. The left auricle is connected to the left ventricle, and the entrance is guarded by the **bicuspid valve**, similar in structure the tricuspid, but with only two cusps. **Semilunar valves** guard the exit to the pulmonary artery and the aorta. These valves consist of three little pockets of tissue which also maintain the one-way flow of blood.

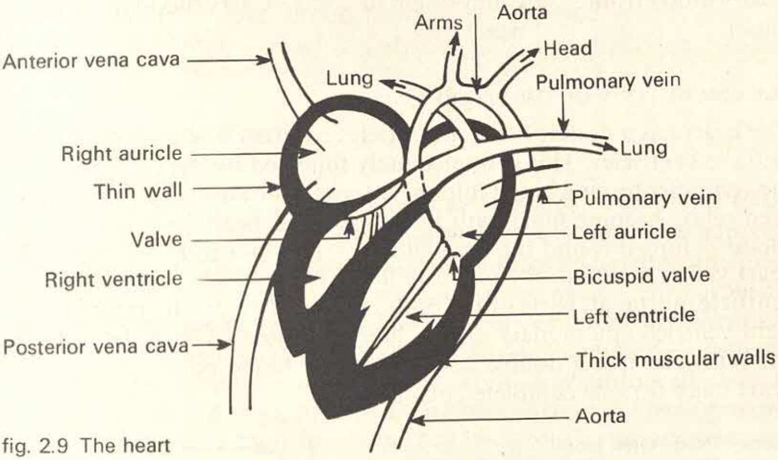

fig. 2.9 The heart

THE BLOOD VESSELS

Arteries take blood from the heart to all parts of the body. The main artery, the **aorta**, splits into different arteries to supply different regions of the body. An artery is a thick-walled blood vessel. The arteries eventually divide into very fine blood **capillaries**. All tissues are well supplied with a network of capillaries. Capillaries are thin-walled, and allow dissolved substances in the blood to diffuse through the walls. The capillaries recombine to form veins. The **veins** combine to form larger veins and eventually become the two main veins entering the heart. Veins are thin-walled blood vessels with valves which maintain a one-way flow of blood.

Arteries, veins and capillaries

Arteries	Veins	Capillaries
Thick muscular walls	Thin walls	Very thin walls
No valves	Valves	No valves
No diffusion	No diffusion	Diffusion through walls
Carry blood from heart	Carry blood to heart	Carry blood to tissues

THE CIRCULATION OF THE BLOOD

The heart has a double beat; the auricles contract first and force blood into the ventricles. This is immediately followed by the contraction of the ventricles forcing blood into the arteries. The auricles and ventricles then relax, become filled with blood, and the heart beat is repeated. Blood is forced round the circulatory system in a series of jerks. The heart valves maintain the one-way flow. The passage of blood is: left ventricle, aorta, all parts of the body, the caval veins, the right auricle, right ventricle, pulmonary artery, lungs, pulmonary vein, left auricle, left ventricle. It is a double circulation; the blood passes through the heart twice for one complete circulation.

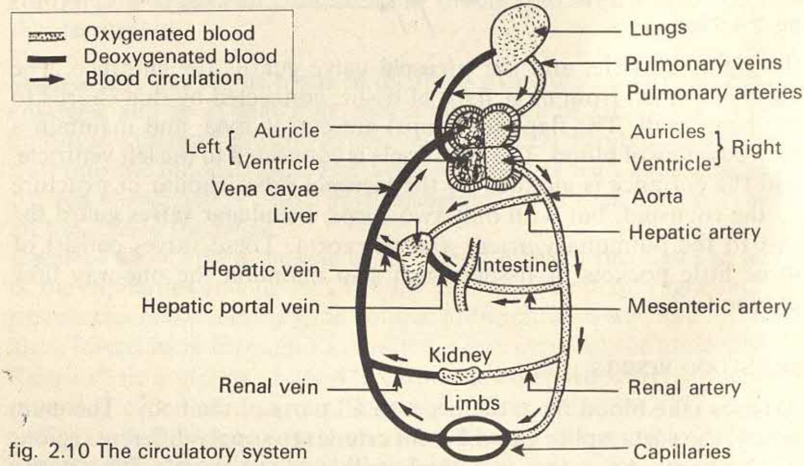

fig. 2.10 The circulatory system

The arterial system. The aorta on leaving the heart branches to give arteries to the head and fore limbs. It continues as the **dorsal aorta** running the length of the body. The aorta branches to the **hepatic artery** (supplying the liver); the **mesenteric artery** (supplying the alimentary canal); the **renal artery** (supplying the kidneys); and then supplies the lower limbs. The **pulmonary artery** from the right ventricle goes to the lungs.

The venous system. Veins from the lower limbs are joined by the **renal vein** (from the kidneys) and the **hepatic vein** (from the liver); these form the **posterior vena cava**. Veins from the head and fore limbs join to form the **anterior vena cava**; these two caval veins enter the right auricle. The **hepatic portal vein** joins the alimentary canal to the liver. The **pulmonary vein** joins the lungs to the left auricle. Movement of muscles pushes blood through the veins; valves ensure a one-way flow.

The circulatory system. Blood flows in an enclosed system from the heart to the arteries, which eventually split into minute capillaries; the capillaries reunite to form veins, which lead back to the heart.

THE COMPOSITION OF BLOOD

1 Red corpuscles

These are small cells, flat and plate-like in shape, with a rim round the edge. The corpuscle walls are thin and elastic, and easily squeezed out of shape, so that the corpuscles can pass through narrow capillaries. The red corpuscles of mammals do not possess nuclei. The corpuscles contain **haemoglobin**, which causes a mass of corpuscles to appear red, and gives the red coloration to blood. The complex compound, haemoglobin, contains iron, making a small quantity of iron an essential in the diet. Red corpuscles are produced in red **bone marrow**; their life is short (4 months), then they 'wear out', and are destroyed in the **spleen**, and some in the liver. The function of red corpuscles is the transport of oxygen by formation of the compound **oxyhaemoglobin**.

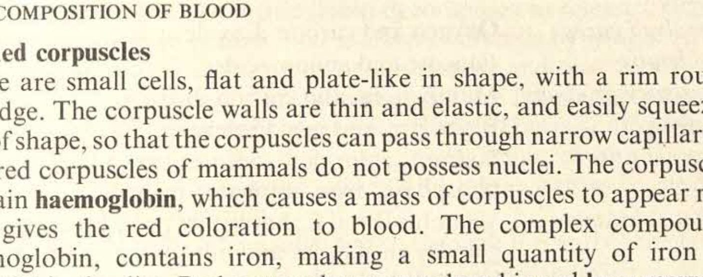

fig. 2.11 Blood corpuscles

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2 White corpuscles

These corpuscles are colourless, have a changeable shape, and possess a nucleus. The nucleus is divided into separate masses joined by fine threads. The white corpuscles are less numerous than red corpuscles, and are larger. They move in a manner similar to entamoeba, using pseudopodia. White corpuscles are capable of reproduction when needed; otherwise they are mainly produced in red bone marrow, while some are produced in **lymph**.

Some white corpuscles act as **phagocytes**; these engulf bacteria in the blood, in the same way as entamoeba engulfs food, and digests the bacteria. Other corpuscles release **antitoxins**, which counteract the toxins produced by bacteria. In local infections, white corpuscles die in attacking bacteria and the dead cells form **pus**. White corpuscles thus reduce infection by bacteria; different types of white corpuscles react in different ways to bacterial attack.

3 Plasma

The blood corpuscles are contained in a pale yellow liquid called plasma, which is 92% water. It contains inorganic salts in true solution, proteins in colloidal solution, foodstuffs and excretory products in solution.

Dissolved gases	Oxygen and carbon dioxide.
Foodstuffs	Glucose and amino-acids.
Excretory products	Mainly urea, and carbon dioxide.
Proteins	Blood proteins, e.g. **fibrinogen**.
Mineral salts	Sodium chloride, sodium carbonate, calcium phosphate, iron sulphate, magnesium chloride.
Other substances	Vitamins B and C; hormones produced in ductless glands; antibodies and antitoxins are all in solution in the plasma.

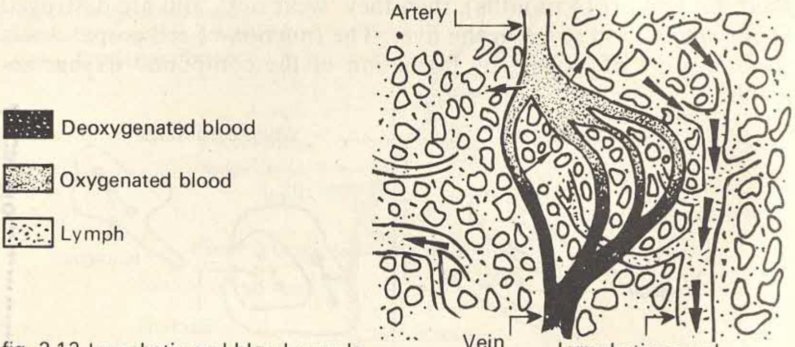


fig. 2.12 Lymphatic and blood vessels

4 Lymph

Blood circulates in the capillaries, and lymph diffuses through the capillary walls. Lymph consists of plasma with small white corpuscles; it passes into the lymphatic spaces between cells, and all cells are bathed by lymph. The lymph is then collected by **lymphatic vessels**; these join to form the **lymphatic system**, which finally becomes one large vessel joining the main veins from the upper limbs. Lymphatic vessels have valves to maintain a one-way flow of lymph. Along the lymphatic vessels are the lymph glands, which produce white corpuscles; lymph glands assist in destroying microbes and toxins.

THE FUNCTIONS OF THE BLOOD

1 Transport

a. Foodstuffs. Glucose and amino-acids diffuse into villi in the small intestine, and dissolve in the plasma, pass through the villi capillaries to the hepatic portal vein to the liver, then through the hepatic vein to the main blood circulation. In blood capillaries, the plasma forms lymph, and the lymph supplies all cells with dissolved foodstuffs.

b. Oxygen and carbon dioxide. Oxygen in the air-sacs diffuses through walls into the capillaries; it dissolves in the plasma, and forms oxyhaemoglobin, a loose chemical compound of oxygen and haemoglobin; this is oxygenated blood, bright red in colour. In the capillaries, oxyhaemoglobin decomposes to release oxygen, which dissolves in plasma, and is taken to all cells by lymph. After tissue respiration, carbon dioxide is released, and dissolves in the lymph. The carbon dioxide is carried by the lymph to the main blood circulation, and is passed to the lungs. This is deoxygenated blood and it is dark red in colour. In the lungs, carbon dioxide diffuses through the capillary walls and the air-sac walls, and is expired during expiration.

c. Inorganic salts. These salts diffuse through the wall of the large intestine, and are delivered to the cells that require them in a manner similar to dissolved foodstuffs.

d. Excretory products. Proteins are broken down to simpler compounds, and eventually to **urea**; urea circulates in the blood stream, and is removed by the kidneys. (Carbon dioxide is also an excretory product.)

2 Defence of the body

a. Wounds. Phagocytes kill and digest invading bacteria. **Fibrinogen** forms long strings of **fibrin**; the fibrin traps red corpuscles, forming a solid mass of blood (a *clot*). The clot dries, forming a *scab*, which excludes bacteria.

b. Against disease microbes. Microbes in the blood release **toxins**, the end products of their nutrition. White blood cells release **antitoxins** to neutralize the toxins. White blood cells and body tissues release **antibodies** in the blood stream; these cause bacteria to clump together and lose their mobility. The clumps of bacteria are digested by phagocytes.

3 Communication

The circulatory and the nervous systems are the two means of communication between the different parts of the body. **Hormones**, from ductless glands, circulate in the plasma, and catalyse reactions in other tissues or organs.

4 **Heat control**

Blood carries heat, produced by the respiration of cells in different tissues and organs, to the skin. The skin regulates body temperature.

Assimilation in nutrition

TISSUE RESPIRATION

The end product of digested carbohydrates (glucose) is delivered to each cell by lymph; oxygen is likewise delivered to each cell. These substances diffuse into the cell. Within each cell, tissue respiration takes place; this is the *release of energy* by the breakdown of glucose through oxidation, aided by enzymes. The end products are carbon dioxide and water, which diffuse out of the cell into the lymph. Energy is released as heat, and as chemical energy. Chemical energy is used to produce changes in protoplasm in the cells, and the enlargement of growing cells (growth of tissues).

ASSIMILATION OF PROTEINS

The end product of digested protein (amino-acids) is delivered to each cell by lymph. The cell *synthesises* proteins from amino-acids, using chemical energy from respiration; this protein builds new tissues or replaces worn-out tissues. Some amino-acids are broken down to glucose and urea; the glucose is used in tissue respiration, and the urea diffuses out of the cell.

ASSIMILATION OF FAT

Glycerol and fatty acids recombine in the *lacteals* of villi, and pass through the lymphatic system to the circulatory system. Fat circulates in the blood as insoluble fat. Some fat is stored in the body as tissue fat, the remainder is oxidised in tissue respiration, after complex changes.

Control of the circulatory system

All chemical substances transported by blood diffuse in to or out of the blood stream. Diffusion only takes place from a solution of higher concentration to one of lower concentration. The concentration of substances in the blood is therefore very important; control of concentration is carried out by the liver and the kidneys.

THE LIVER

The liver is a large, red coloured, lobed organ situated above and to the right of the stomach, and below the diaphragm. It is richly supplied with blood from the hepatic artery and the hepatic portal vein; blood collected from a large network of capillaries leaves by the hepatic vein. The **gall bladder** is situated between the lobes. The **bile duct** leads from the gall bladder to the pancreatic duct.

Functions of the liver

1 All digested food passes through the hepatic portal vein to the liver, and the liver controls the concentration of glucose and amino-acids in the blood.
2 Excess glucose is converted to glycogen (animal starch) and stored in the liver. When there is a need, glycogen is converted back to glucose; the glucose passes into the blood stream for use in respiration.
3 Excess amino-acids are broken down to glycogen and urea. This is called **deamination**. The glycogen is stored, and the urea is released into the blood stream for excretion by the kidneys (page 26).
4 Liver cells produce bile. Bile is stored in the gall bladder.
5 Any poisons or toxins absorbed in the small intestine are neutralised in the liver. This is **detoxication**. **Antibodies** are also produced in the liver.
6 The liver produces the soluble blood proteins dissolved in plasma.
7 The many activities of the liver liberate a considerable amount of heat; this heat helps to warm the body.

THE SPLEEN

The spleen is a dark red, oval-shaped organ, on the left side of the stomach, just below the liver. It destroys worn-out red corpuscles; it stores compounds of iron to provide the iron needed in haemoglobin. It is a reservoir for red corpuscles, which are released to replace blood losses; the water for the plasma is supplied by the body.

The excretory system

The end products of nutrition are carbon dioxide and urea; these are the excretory products.

THE EXCRETORY ORGANS

The kidneys

There are two kidneys, each a bean-shaped organ, situated near to the backbone, one on either side, just below the waist. Each kidney consists of an outer, red coloured **cortex**, and an inner, paler **medulla**. A tube, the **ureter**, leads away from the concave surface of the kidney. The ureter is swollen at the juncture with the kidney, to form the **pelvis**. A portion of the kidney, the **pyramid**, juts into the pelvis. Numerous **uriniferous tubules**, which start in the cortex, lead into the medulla, join together, and finally combine into one duct which enters the pelvis through the pyramid. Each kidney is supplied with blood from the **renal artery**, and blood returns through the **renal vein**; both vessels are short and wide, giving the kidneys a rich supply of blood.

Each uriniferous tubule has a capsule at its end; a knot of capillaries fills the capsule. The tubule then forms a loop, also covered with a network of capillaries. The tubule then enters the medulla, and finally joins the duct in the pyramid. All the capillaries are connected to the renal artery and renal vein.

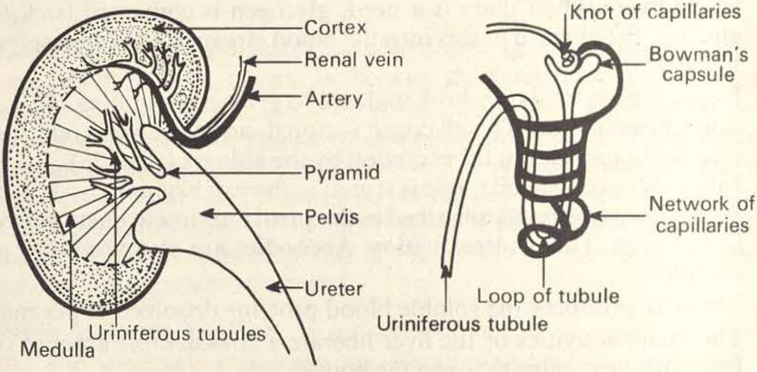


fig. 2.13 The kidneys: structure and filtration

The function of the kidneys

The capsule filters out urea, glucose, and inorganic salts from the blood in the capillaries, and also removes water from the plasma. This solution then passes into the loop below the capsule. Reabsorption now takes place into the capillaries surrounding the loop. If the plasma is too dilute, less water and more glucose and salts are absorbed. If the plasma is too concentrated, more water and less glucose and salts are reabsorbed. Urea is not reabsorbed. The product of this process is **urine**. The kidneys extract urea, which is a waste nitrogenous product, from the plasma in the capillaries, collect the urine in tubules, and pass it along the **ureter** for temporary storage in the bladder. The bladder empties periodically through the **urethra**, which leads to the **uro-genital system**.

Lungs

The lungs are also excretory organs as they eliminate carbon dioxide, the other excretory products, from the body.

Water intake and loss

Water is an important substance for the chemical reactions of the body. Digestion is carried out with solutions of soluble foodstuffs; the circulatory system uses water in plasma. Water is obtained by drinking, and also from food. Losses of water occur from:

1 **Expired air** – air-sacs are moist, and expired air is saturated with water vapour.

2 **Urine** – this is the major source of loss.
3 **Sweat** – sweat uses a lot of water when the body experiences high temperatures, e.g. tropical conditions.
4 **Other ways** – a little water is lost through tears, and losses of blood also cause a loss of water.

The control of water in the body
Any exceptional loss, e.g. loss of blood or heavy sweating, causes thirst; water is then drunk to maintain the fluid content of the body. The liver and the kidneys control the concentration of dissolved substances in the plasma, and the kidneys eliminate water to maintain the correct concentration.

Temperature control of the body

THE SKIN

The skin of a mammal consists of an outer layer, the **epidermis**, and and inner layer, the **dermis**. The epidermis has two principal layers, a **horny layer**, containing dead cells, and a **malpighian layer**, containing living, growing cells. The dermis contains the remaining tissues. **Hair** grows from hair **follicles**, which are pits deep in the dermis. An **erector muscle** is attached to the base of the hair, and raises the hair. **Sebaceous glands** are in the hair follicles. In the dermis are **sweat glands**, surrounded by capillaries, connected to **sweat ducts**, which open into the horny layer through **sweat pores**. **Nerve fibres** in the dermis lead to **nerve endings** situated just below the epidermis. The whole of the dermis contains a network of blood capillaries. At the base of the dermis are clusters of **fat cells**.

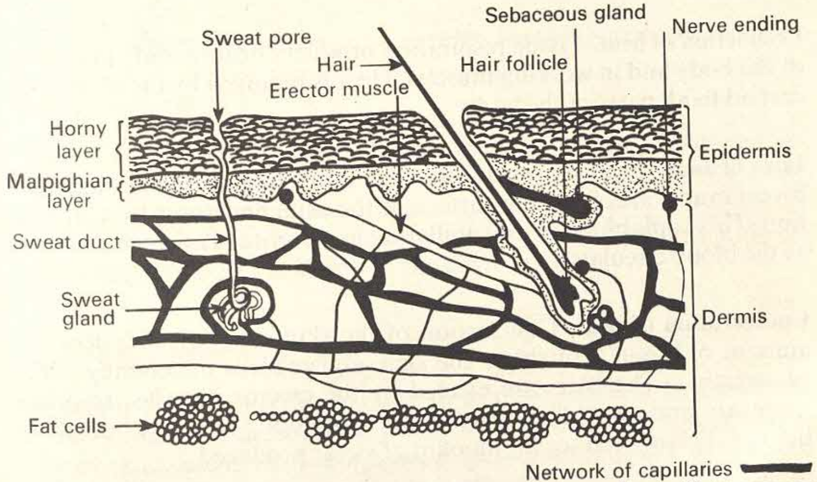


fig. 2.14 Section through the skin of a mammal

FUNCTIONS OF SKIN STRUCTURES

Structure	Function
Horny layer	Acts as a waterproof layer.
Malpighian layer	For the production of new cells.
Sweat glands	For the production of sweat.
Hair	To trap air so as to provide an insulating layer for protection against heat and cold.
Erector muscle	To move hair into an erect position.
Sebaceous glands	To secrete oil for waterproofing hair.
Nerve endings	For the perception of stimuli.
Nerve fibres	To carry impulses to the central nervous system.
Blood capillaries	Contract,expand in heat control.
Fatty tissues	Provide insulation against cold.

TEMPERATURE CONTROL

The chemical changes taking place in cells are catalysed by enzymes; enzymes have an *optimum* temperature (about 98° F) at which they are most effective. The temperature of a healthy body is kept at 98° – 99° F for this reason.

Production of heat. Tissue respiration produces heat, mainly in organs of the body and in working muscles. Heat is removed by the blood and carried to all parts of the body.

Loss of heat. Heat is lost during excretion, breathing and sweating. Sweat evaporates from the surface of the skin, and cools by evaporation. This cools blood in the capillaries, and eventually the whole body, as the blood circulates.

Conservation of heat. Contraction of the skin capillaries reduces the amount of blood brought to the skin, and reduces the cooling effect of sweating. The hairs are erected by the erector muscles, trapping more air and providing better heat insulation. Nerves controlling the sweat glands reduce the amount of sweat produced.

Temperature control. Heat losses by sweating are regulated by control from the central nervous system, so that the body temperature is maintained. During violent exercise, the skin capillaries expand, sweating is increased, and the extra heat produced in the muscles is lost through the cooling effect of heavy sweating.

The nervous system

NERVE TISSUE

Nerves. Nerve cells, or neurons, consist of an actual cell with a nucleus; the cell has one or two long *projections*, at the end of which are a varying number of outgrowths. The projections have an insulating sheath; **axons** are projections carrying **impulses** away from the cell, **dendrons** carry impulses to the cell. The outgrowths from axons and dendrons are called **dendrites**. Dendrites of one cell intermix with dendrites from another cell; this joining is called a **synapse**. Nerve fibres are composed of bundles of axons and dendrons, and the fibre has a protective sheath.

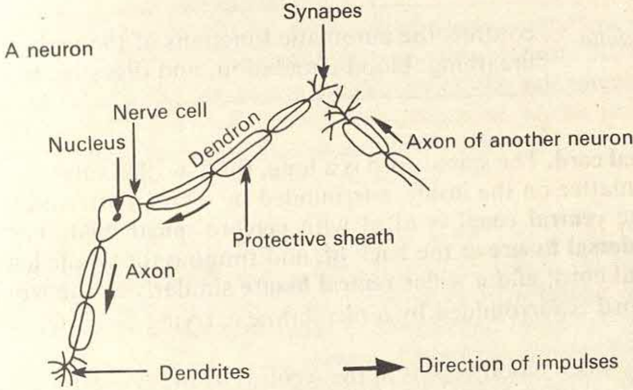


fig. 2.15 Nerve cells

Nervous system. Nerve fibres are connected to **sense organs**, which initiate impulses. Sensory nerve fibres conduct impulses to the central nervous system, which initiates further impulses, sent by motor nerve fibres (to muscles), or by secretory nerve fibres (to glands). The sense organs thus produce a reaction to the environment.

THE CENTRAL NERVOUS SYSTEM

The brain. The brain is divided into three main regions, the **cerebrum**, the **cerebellum**, and the **medulla**. The cerebrum fills most of the **cranium**, or bony skull, and is divided into two hemispheres. The left hemisphere controls the right-hand side of the body, and the right hemisphere the left-hand side of the body. The cerebrum consists of **grey matter**, mainly composed of the cell bodies of nerve cells, on the outside, and **white matter**, consisting mainly of nerve fibres, inside. The surface of the cerebrum is much folded, and divided into lobes. The cerebellum is much smaller and is situated below the cerebrum, at the back of the cranium. Its surface is also much folded, and consists of grey matter; white matter is contained inside. The medulla is a cone-shaped swelling at the top of the spinal cord; it contains white matter on the outside and grey matter on the inside. The brain is surrounded by a thin membrane, the **pia mater**, which carries blood capillaries and lymph vessels; its outside surface is covered in fluid, which prevents friction between the containing bones and the delicate brain structures.

The cerebrum	controls all mental activity and voluntary actions.
The cerebellum	coordinates and controls movement of the body.
The medulla	controls the automatic functions of the body, such as breathing, blood circulation, and digestive processes.

The spinal cord. The spinal cord is a long, thick-walled tube. It consists of grey matter on the inside, surrounded by white matter on the outside. The **central canal** is filled with **cerebro-spinal fluid**. There is a narrow **dorsal fissure** at the back of, and running the whole length of, the spinal cord, and a wider **ventral fissure** similarly at the front. The whole cord is surrounded by a membrane carrying blood vessels, the pia mater.

There are also blood vessels in the ventral fissure. A series of **paired nerves** join the spinal cord at various points along it. Each nerve has

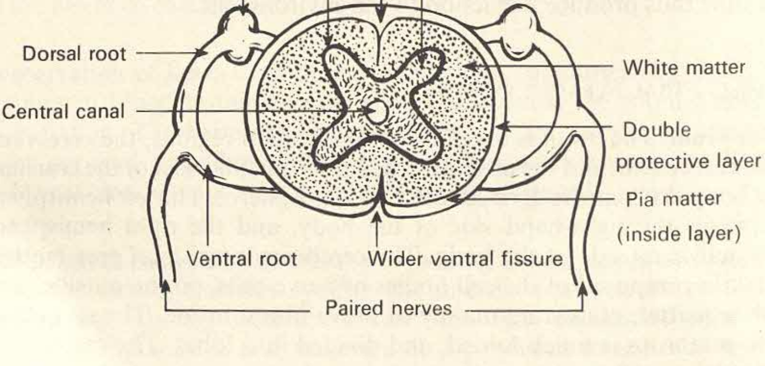


fig. 2.16 The spinal chord

two roots, a **dorsal** and a **ventral** root. On the dorsal root is a **ganglion**, consisting of nerve cells of neurons. The grey matter, which consists of nerve cells of neurons, forms four horns, with each horn giving rise to a root of the paired nerves. The dorsal root contains sensory root fibres, and the ventral root contains motor nerves. The roots join to form a mixed nerve.

The paired nerves from the spinal cord branch, join, and rebranch, to cover the body with a network of nerve fibres. These nerve fibres end in **sense organs,** situated (a) in the skin, eyes, ears, tongue, and nasal passage, for observing the environment, and (b) in the organs and tissues of the body to control the different systems.

The sympathetic nervous system

In addition to the nervous system described above, a network of nerve fibres and ganglia form a sympathetic nervous system. This system coordinates body functions with conditions of the environment. The quickness of heart beat, the secretion of digestive juices, the rate of peristalsis are controlled by the sympathetic system.

THE EYE

The eyeball is roughly spherical in shape, with a bulge at the front. The outside layer, the **sclerotic**, is tough muscular tissue; the next layer, the **choroid**, is shiny and black; the inside layer is the **retina**, which has nerve endings from the **optic nerve**. The sclerotic bulges at the front, to form a *transparent* layer, the **cornea**. Behind the cornea is a **crystalline lens**, held by suspensory ligaments to a ring of muscle, **the ciliary muscle**. The ciliary muscle is attached to the sclerotic at the end of the choroid. In front of the lens is a circular coloured muscle, the **iris**; the hole in the iris forms the **pupil**. Behind the lens, the eyeball is filled with **vitreous humour**; in front, it is filled with **aqueous humour**. The front of the eye is covered with a thin transparent membrane (a continuation of the lining of the eyelid), called the **conjuctiva**.

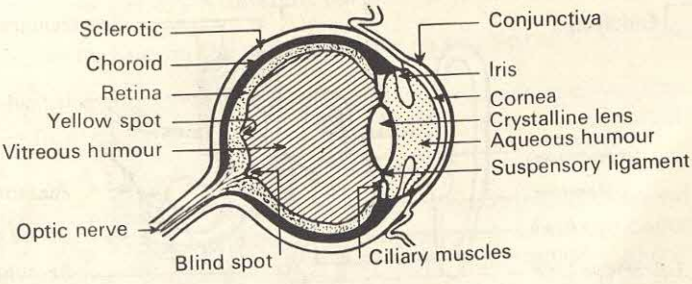


fig. 2.17 The eye

FUNCTIONS OF THE PARTS OF THE EYE

Part	Function
Conjunctiva	Admits light; protective agent against germs.
Cornea	For the refraction of light.
Sclerotic	To give shape to the eye; to protect the inner parts.
Choroid	Carries blood vessels; black pigment prevents the reflection of light.
Retina	For the perception of light rays.
Optic nerve	For the transmission of *impulses* from the retina to the brain.
Iris	For controlling the amount of light to the retina.
Lens	For focusing light rays on the retina.
Suspensory ligaments	For holding the lens in position.
Ciliary muscles	For controlling the curvature of the lens.
Aqueous humour	For maintaining the shape of the eye.
Vitreous humour	For maintaining the shape of the eye.
Yellow spot	Point of most acute vision.
Blind spot	Provides entrance for nerve fibres to retina.

THE EAR

There are three separate compartments of the ear, the outer, middle and inner ear.

The outer ear is a passage which secretes wax, and ends in a membrane, the **eardrum**, which connects to the middle ear.

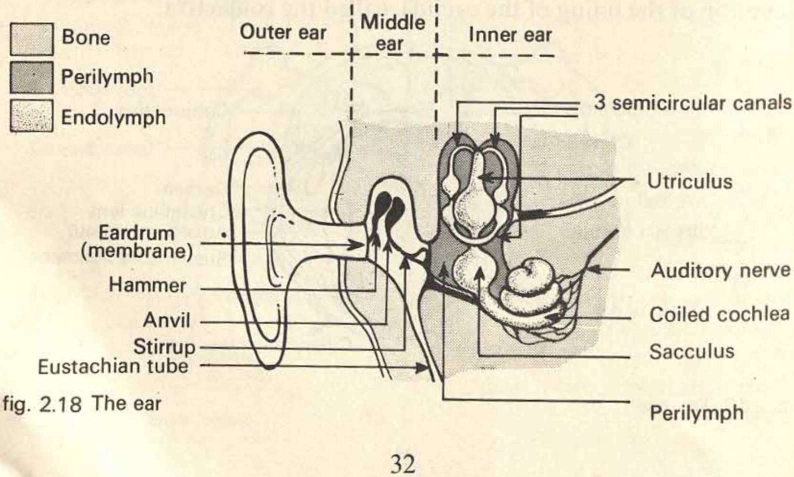


fig. 2.18 The ear

The middle ear contains three bones, the **hammer**, **anvil**, and the **stirrup**, all of which connect the eardrum with a membrane dividing the middle from the inner ear.

The inner ear contains membranous hollow sacs and tubes filled with a liquid, **endolymph**. These sacs and tubes are in a bony structure of the cranium, and a liquid, **perilymph**, separates the membranous structures from the bone. The structures consist of two bulbs, the **sacculus** and the **utriculus**, and from the sacculus there extends a coiled tube, the **cochlea**. Three **semicircular canals** arise from the utriculus. The three are mutually at right angles. The **auditory nerve** connects the brain with the cochlea, and also with the semicircular canals.

FUNCTIONS OF THE PARTS OF THE EAR

1 External vibrations are caught by the *external ear*, and passed to the eardrum.
2 The vibrations are passed by the bones of the *middle ear* to the membrane of the inner ear.
3 The perilymph and endolymph carry the vibrations to all parts of the *inner ear*.
4 Nerve endings in the cochlea are stimulated by the vibrations and the auditory nerve conducts impulses to the brain.
5 The semicircular canals are stimulated by movements of the head, and the sense of balance is controlled by the nerves from these canals.
6 The Eustachian tube connects the pharynx with the middle ear and ensures that the pressure in the middle ear is atmospheric pressure, i.e. the same pressure on both sides of the eardrum.

THE SENSE ORGANS

Touch. Nerve endings in the dermis receive **stimuli** and the nerve fibres transmit impulses to the central nervous system. Associated with touch are the sensations of heat, cold, and pain; these stimuli are received by different nerve endings in the dermis; sensitivity to all these sensations varies on different parts of the skin.

Smell. Nerve endings in the nasal passages receive appropriate stimuli.

Taste. Small swellings on the tongue, called **taste buds**, receive stimuli; there are four stimuli: sweet, acid, salty, bitter; taste is a combination of these.

Internal sense organs. Nerve endings in the various organs respond to stimuli to keep the body functioning properly, e.g. when the contents of the stomach are sufficiently acid, the pyloric muscle opens, and food enters the duodenum; control is exercised by nerve endings in the stomach.

The senses: sight, hearing, taste, smell, and touch, make the body aware of its environment. All **receptors** receive stimuli, and send impulses along nerve fibres to the central nervous system.

Reflex arc

A stimulus (e.g. a hot object) is perceived by a nerve ending (touch organ), which initiates an impulse. The impulse travels along the sensory nerve to the central nervous system (spinal cord). The impulse is relayed by a synapse to a motor nerve, and the impulse travels along the motor nerve to the muscle. Action is produced by the stimulus: the hand is withdrawn. The action produced by a reflex arc is either muscular movement, or secretion from a gland.

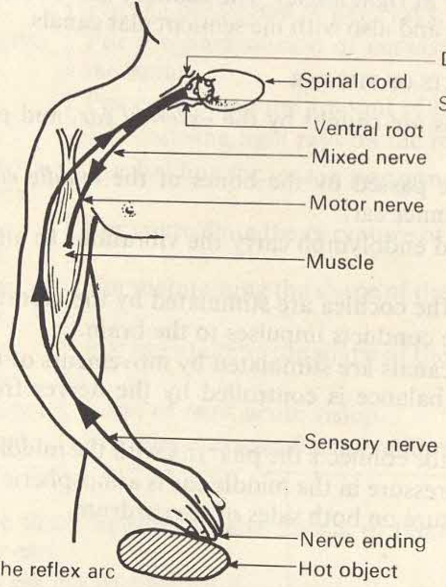


fig. 2.19 The reflex arc

Conditioned reflex. Many reflex arcs exist at birth; in addition, synapses can form from repetition of an action, and then a **conditioned reflex arc** is formed, e.g. the reflex actions learnt in driving a car.

Voluntary actions

Important senses, e.g. sight, hearing, smell, balance, are directly connected to the brain; other senses are connected to the spinal cord. For a voluntary action, a stimulus is perceived by a sense organ, impulses pass along the sensory nerve to the spinal cord, and thence to the brain for interpretation. A motor impulse is initiated in the brain, passes along the spinal cord and the motor nerve to produce an action. The action produced is usually muscular movement.

Movement of the body

THE SKELETON

The axial skeleton consists of a vertebral column, to which four limbs and the skull are attached. Ribs, attached to the upper end of the vertebra, enclose the thoracic cavity.

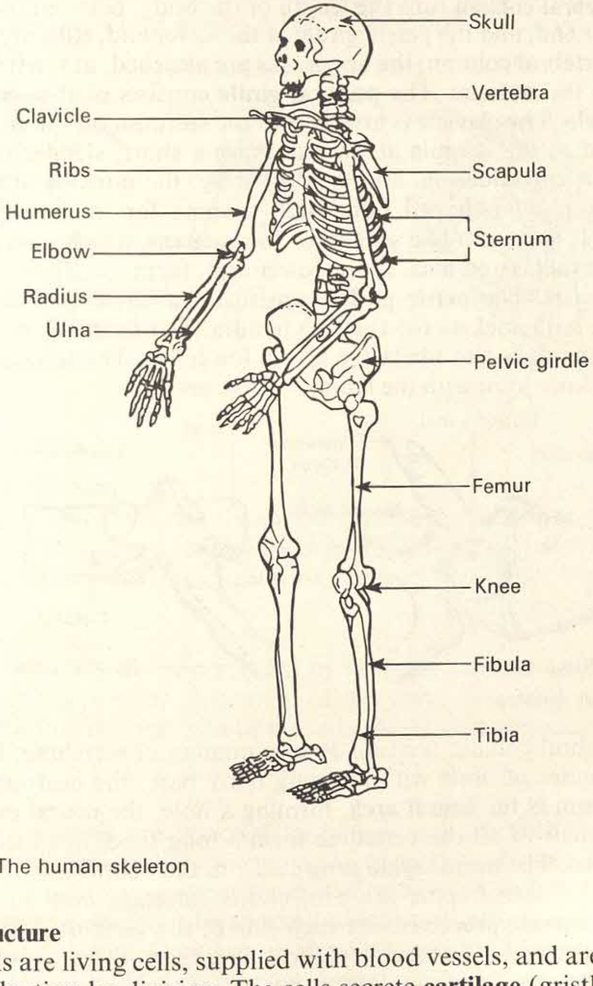


fig. 2.20 The human skeleton

Bone structure

Bone cells are living cells, supplied with blood vessels, and are capable of reproduction by division. The cells secrete **cartilage** (gristle) which surround them and forces them apart. Older cells secrete calcium salts, which harden cartilage into bone.

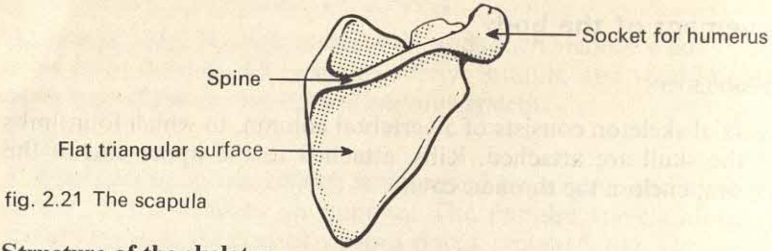


fig. 2.21 The scapula

Structure of the skeleton

The **vertebral column** runs the length of the body, between the **skull** at the upper end, and the pelvic girdle at the lower end. **Ribs** are attached to the vertebral column; the upper ribs are attached, at the front of the body, to the **sternum**. The **pectoral girdle** consists of the **scapula** and the **clavicle**. The clavicle is attached to the sternum on the front of the body and to the scapula at the side; it is a short, slender bone. The scapula is embedded in, and supported by, the muscles of the back; it is a triangular-shaped bone with a spine for the attachment of muscles. It has a cup-like socket for the **humerus**, which is in the upper arm. The **radius** and **ulna**, in the lower arm, form the elbow joint with the humerus. The **pelvic girdle** consists of a circle of bones, fused together, with sockets for the two femurs. The **femur** is in the upper leg and the **tibia** and **fibula** are in the lower leg. The tibia and fibula form the knee joint with the femur.

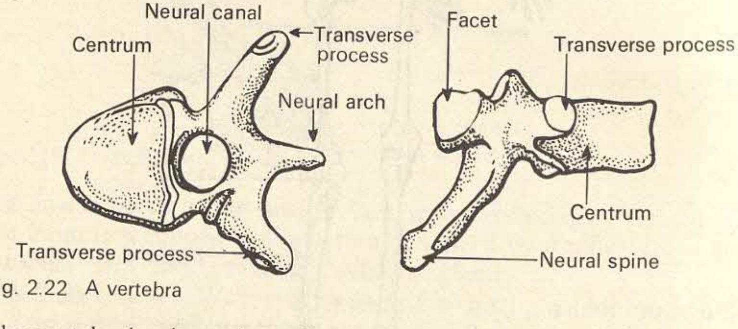


fig. 2.22 A vertebra

The vertebral column is made up of a number of **vertebrae**. Each is a solid cylinder of bone with a strong bony base, the **centrum**. Above the centrum is the **neural arch**, forming a hole, the **neural canal**. The neural canals of all the vertebrae form a long tube, in which lies the spinal cord. The **neural spine** projects from the neural arch. On either side of the neural spine are projections sideways and downwards, called **transverse processes**. On each side of the vertebra, between the neural spine and a transverse process, is a **facet**, a semi-circular projection of bone, which fits into a hollow of the vertebra below. The facets prevent the vertebrae slipping across each other and damaging the spinal cord.

Functions of the skeleton

1 To give support and shape to the body.

2 To allow locomotion (i.e. movement) by the movement of bones, turning by means of joints, through the action of muscles.

3 To give a protective covering for vital organs (e.g. the ribs and skull protect the heart, lungs and brain).

JOINTS

Hinge joints (elbow, knee) allow movement in one direction.
Ball and socket joints (hip, shoulder) allow movement in any direction.
Sliding joint (vertebra) allows bones to slide slightly over each other.

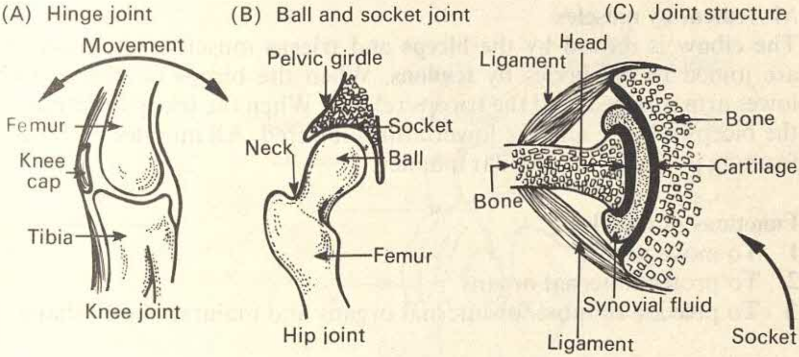


fig. 2.23 Joints

Structure of joints

The head of one bone and the socket of the other bone are covered in cartilage. Between the two bones is **synovial fluid**, secreted by tissues enclosing the joint. Tough **ligaments** hold the two bones together.

Function of joints

The wearing of bones is prevented by the synovial fluid and cartilage. The ligaments prevent *dislocation* of the joint. The head and socket structure allow the bones to be moved relative to each other.

MUSCLES

Voluntary muscles are attached to bones, and are able to contract quickly, and vigorously, on response to an impulse from a nerve. All bones are moved by voluntary muscles. The tissue in voluntary muscles has a striped appearance. **Involuntary muscles** cover the internal organs, and contract slowly. The tissue in these muscles has a *smooth appearance*. Muscles can only contract and relax; all voluntary muscles are found in pairs, acting in opposition to produce the necessary backward and forward movement of a bone.

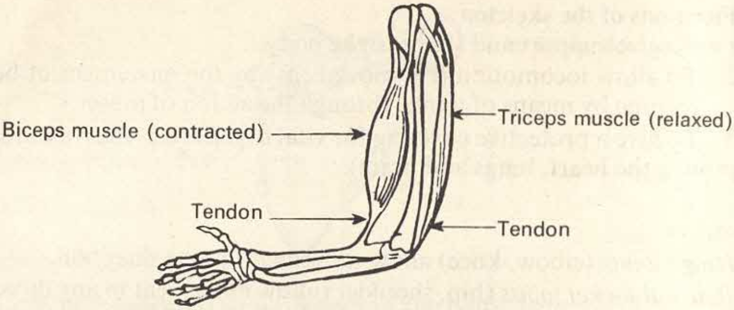


fig. 2.24 Muscular action

Movement by muscles

The elbow is moved by the **biceps** and **triceps** muscles. The muscles are joined to the bones by **tendons**. When the biceps contracts, the lower arm is raised, and the triceps relaxes. When the triceps contracts, the biceps relaxes, and the lower arm is lowered. All muscles on bones forming joints act in a similar manner.

Functions of muscles

1. To move joints.
2. To protect internal organs.
3. To provide support for internal organs and maintain body shape.

The reproductive system

THE FEMALE REPRODUCTIVE SYSTEM

Structure. Two ovoid-shaped **ovaries** are situated on the abdominal wall below the kidneys; they have a blistered appearance. Near each ovary is a funnel-shaped opening to the **oviducts** (or fallopian tubes). These are long narrow tubes leading to the uterus. The **uterus** is a pear-shaped organ with thick muscular walls; it is connected to the vagina by a narrow tube, the **cervix**, which projects into the vagina. The **vagina** is a tube leading to the exterior; it is joined by the **urethra**, and both have a common exit in the *vestibule*, which is situated close to, and in front of, the *anus*.

Functions of the female reproductive organs

The ovaries	are for the production of **ova** (or eggs).
The oviducts	are for the passage of ova to the uterus; they are also the region of fertilisation of ova by sperms.
The uterus	is for the attachment of the **embryo**, and for the feeding of the embryo.
The vagina	is for the reception of sperms. It is also the birth canal by which the infant is born.

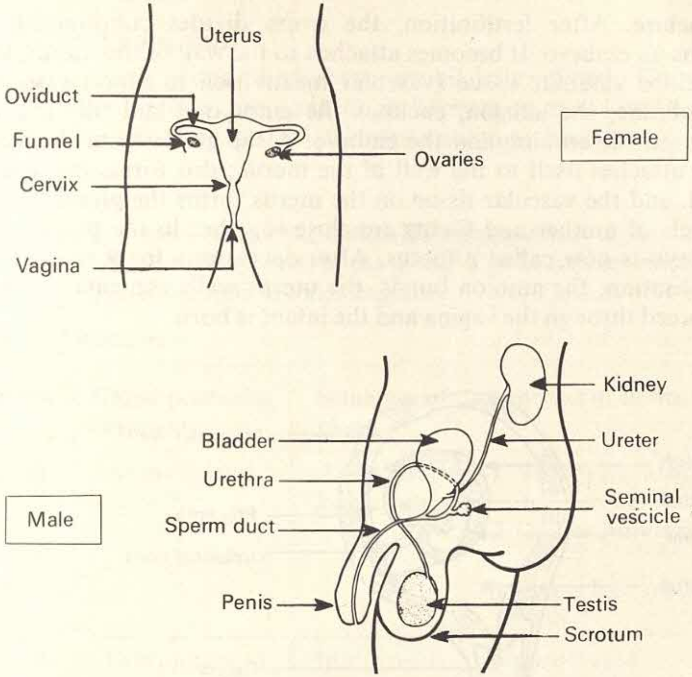


fig. 2.25 The reproductive organs

THE MALE REPRODUCTIVE SYSTEM

Structure

Two round-shaped **testes** are situated in the **scrotum**, a sac-like structure. The **sperm duct** leads from the testes to the *urethra*. It is joined by a duct from the **seminal vesicles**. The sperm duct and the urethra unite just after the urethra leaves the bladder. The urethra passes down the **penis**, an organ of muscular erectile tissue. The urethra is the combined exit for urine and sperms.

The whole system is the uro-genital system; the kidneys are joined to the bladder by two ureters. (This structure is common to both sexes.)

Functions of the male reproductive organs

The testes	are for the production of **sperms**.
The seminal vesicles	store **seminal fluid**, a liquid providing the means for sperms to swim to the ova.
The penis	is for the insertion of sperms into the vagina.

THE FOETUS

Structure. After fertilisation, the ovum divides continuously and forms an embryo. It becomes attached to the wall of the uterus, which develops vascular tissue (vascular means rich in blood vessels). A membrane, the **amnion**, encloses the embryo. Fluid fills the space between the amnion and the embryo. A sac grows from the embryo and attaches itself to the wall of the uterus; this forms the **umbilical cord**, and the vascular tissue on the uterus forms the **placenta**. Blood vessels of mother and foetus are close together in the placenta. The embryo is now called a foetus. After developing for 9 months from fertilisation, the amnion bursts, the uterus walls contract, the foetus is forced through the vagina and the infant is born.

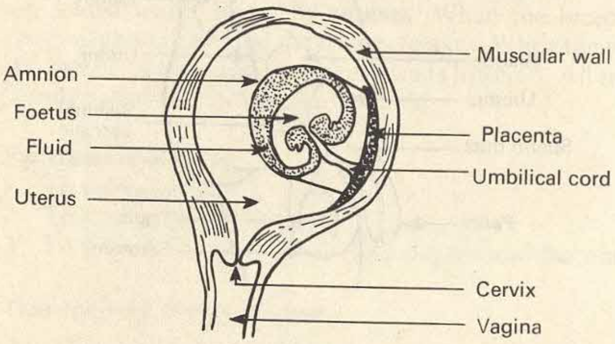


fig. 2.26 The human embryo

Functions of the organs of the foetus

The placenta	is the region in which dissolved substances pass from mother to foetus, and waste products pass from foetus to mother.
The umbilical cord	contains the blood vessels supplying the foetus from the placenta.
The amnion	and the fluid it contains protect the foetus against knocks.

Menstruation. If the ovum is not fertilised, it and the unused vascular tissue are discharged. This occurs every 28 days.

SECONDARY SEXUAL CHARACTERISTICS

Puberty. Between the ages of 11 and 14 years, the reproductive organs develop and produce sperms or ova. In males, the voice breaks, and facial hair grows. In females, the breasts swell and the thighs broaden. The breasts contain **mammary glands**, which secrete milk after the birth of the infant.

COORDINATION IN THE BODY

The separate systems described above are all inter-related. The circulatory system provides the connection between most systems, and it also provides a further method of coordination, by hormones.

HORMONES

Ductless glands release chemicals, called **hormones**, which *diffuse* into the blood stream through the wall of the gland. The hormones *catalyse* reactions in other tissues, or in other organs.

Functions of hormones

Hormone	Gland producing hormone	Situation of gland	Function of hormone
Adrenalin	Adrenal gland	Above the kidney	**1** Increases rate of heart beat **2** Dilates pupils of eye **3** Erects hair on head
Thyroxin	Thyroid gland	In the neck	Controls rate of nutrition
Insulin	Pancreas	Loop of duodenum	Controls glucose-glycogen conversion, i.e. blood sugar content
— —	Testes Ovaries		These hormones affect sexual characteristics
—	Pituitary	In brain cavity	**1** Controls rate of growth **2** General coordination of ductless glands

Hormones bring about slower changes, which may be longer lasting; they complement the changes of the nervous system, which are rapid and shorter lasting. The general coordination of the body and all its systems depends mainly on the functioning of the hormones; good physical **health** is the result of correct functioning.

3 Diet and deficiency diseases

Chemical substances

ELEMENTS

An **element** is a substance which cannot be decomposed into simpler substances by chemical means. All *metals* are elements. The more common elements include *carbon* (a black solid), *hydrogen* (a colourless gas), and *oxygen* (a colourless gas). The smallest particle of an element is an **atom**.

COMPOUNDS

When elements are combined together chemically, they form a **compound**. *Water* is a compound of hydrogen and oxygen (H_2O), *carbon dioxide* is a compound of carbon and oxygen (CO_2). The smallest particle of a compound is a **molecule**.

ORGANIC COMPOUNDS

The chemical compounds produced by living things are called organic compounds; these compounds all contain the element carbon.

INORGANIC COMPOUNDS

These chemical compounds are usually the salts of metals, called **mineral salts**, or substances formed from them.

ACIDS AND BASES

An **acid** is a substance which (1) turns blue litmus red, and (2) can have hydrogen liberated from it by a metal. A **base** is a substance which neutralises an acid to form a **salt** and water. An **alkali** is a soluble base; it turns red litmus blue. Acids and bases can be either organic or inorganic compounds.

Carbohydrates

PHOTOSYNTHESIS

Green plants contain **chlorophyll**, the green pigment in leaves, which *catalyses* certain chemical reactions in the presence of sunlight. The plants take in carbon dioxide and water, and, using light energy from the sun, form glucose, then sucrose, then starch.

$$\textbf{carbon dioxide + water (+ energy)} \xrightarrow{\textbf{chlorophyll}} \textbf{glucose + oxygen}$$

$$\textbf{2 molecules glucose (+ energy)} \xrightarrow{\textbf{chlorophyll}} \textbf{1 molecule sucrose}$$
$$\textbf{+ 1 molecule water}$$

$$\textbf{n molecules glucose (+ energy)} \xrightarrow{\textbf{chlorophyll}} \textbf{1 molecule starch}$$
$$\textbf{+ n molecules water}$$

STATE INSTITUTE OF EDUCATION
Govt. of West Bengal

CARBOHYDRATES

Glucose is a simple sugar (monosaccharide) with formula $C_6H_{12}O_6$. **Sucrose** is a complex sugar (disaccharide) with the formula $C_{12}H_{22}O_{11}$. **Starch** is a very complex compound, called a polysaccharide; its formula is $(C_6H_{12}O_6)_n$. Other sugars found in plants include **fructose** (a monosaccharide) and maltose (a disaccharide). All these compounds are **carbohydrates**, so called because they all contain carbon, hydrogen and oxygen, and the atoms of hydrogen and oxygen are in the same proportions as in water.

SUGARS

There are many different sugars (four have been named above.) All have a sweet taste, and all are soluble in water. All monosaccharides and some disaccharides reduce **Fehling's solution** to red *cuprous oxide*; these are called reducing sugars. Maltose is a *reducing* disaccharide; sucrose is a *non-reducing* disaccharide.

Test for sugars

1 On heating, they char to carbon.
2 Add **Fehling's solution** to the sugar solution, warm the test-tube in boiling water; a *red precipitate* is formed.
3 Add a few drops of hydrochloric acid to the sugar solution; boil the solution for 3 minutes; add **Fehling's solution**, and a *red preciptate* is formed.

Test 2 is for a *reducing sugar*, test 3 is for a *non-reducing* sugar; the acid *hydrolyses* the disaccharide to a monosaccharide.

STARCH

Starch is insoluble in water, and does not have a sweet taste. Starch can be changed in a plant by photosynthesis to **cellulose**. Cellulose has a molecule even larger than starch; cellulose is also a carbohydrate. Tests for sugars give a negative result with starch.

Test for starch

Add 2 drops of *iodine solution*; if starch is present a *deep blue colour* is formed. Sugars have no reaction with iodine.

ENERGY PROVIDING FOODS

Carbohydrates are digested in the body to glucose. Glucose is oxidised, during tissue respiration, to carbon dioxide and water, and energy (for living processes) is released. Digestion and respiration are thus opposite processes to photosynthesis. Carbohydrates are **energy providing foods**.

Carbohydrates in diet. Carbohydrate is usually provided in a *diet* as starch. Common sources of starch are rice and potatoes. Their use as an energy providing food is compared with sucrose in the table below.

Energy from carbohydrates

Part of body	Starch	Sucrose
Mouth	Some starch $\xrightarrow{\text{PTYALIN}}$ maltose	No action
Stomach	No action	No action
Duodenum	all starch $\xrightarrow{\text{AMYLASE}}$ maltose	No action
Small intestine	Maltose $\xrightarrow{\text{MALTASE}}$ glucose	Sucrose $\xrightarrow{\text{INVERTASE}}$ glucose + fructose
Villi	Glucose absorbed into blood capillaries, carried by hepatic portal vein to the liver.	
Liver	Excess glucose stored as glycogen, reconverted when necessary. Concentration of glucose kept constant in plasma.	
Capillaries	Plasma forms lymph; takes dissolved glucose to all cells.	
Cells	Respiration: glucose oxidised to carbon dioxide and	

(Note: Fructose is absorbed and assimilated in the same way as glucose.) The body can digest starch and sugars, but not cellulose.

Enzymes

HYDROLYSIS OF CARBOHYDRATES

The breaking down of starch to disaccharides, or of disaccharides to monosaccharides, is called hydrolysis (i.e. breaking by water). Carbohydrates can be hydrolysed by acids or alkalis (test 3 for sugars); the reaction is slow. With enzymes, the same reaction is much quicker. The enzyme *catalyses* the reaction.

CATALYSTS

A catalyst is a substance which increases the speed of a chemical reaction, but does not undergo any change itself.

All enzymes are catalysts; most are *specific* in their action, i.e. they only catalyse one reaction (e.g. maltase catalyses the change of maltose to glucose). The actions of enzymes are altered by temperature; those in the body function best at 37°C. (body heat); they are also affected by acidity and alkalinity (e.g. ptyalin functions in alkaline solution, is stopped by acid solution).

Proteins

FORMATION OF PROTEIN

Plants absorb **nitrates**, such as potassium nitrate, from the soil, through root hairs. These nitrates, in solution, pass through the root and stem to the leaves. There the process of photosynthesis forms substances, called **amino-acids**, from carbon dioxide, water and the nitrates. **Amino-acids** contain the elements carbon, hydrogen, oxygen and nitrogen. They are organic acids with a group of atoms containing nitrogen (the formula of this group is NH_2).

A further process of photosynthesis builds up molecules of **protein** by combining different amino-acid units. All plants make a little protein, as protoplasm is formed from different proteins. Some plants, such as beans and peas, make a lot of protein and store it in their seeds.

Tests for proteins

1. Heat the protein with *soda lime*. Test with *red litmus* for *ammonia gas*, which turns *litmus blue*.
2. Add a 5% solution of *sodium hydroxide* to the protein; then add two drops of 1% copper sulphate. A violet coloration shows the presence of protein (Biuret test).

BODY BUILDING FOODS

Proteins are digested by the body to amino-acids. The amino-acids enter the cells in the body by diffusion, and, using the energy available from respiration, are built up into proteins. The proteins formed in this way are used by growing cells to make protoplasm, and used by other cells in the living processes of the cell. Proteins are **body building foods**.

Proteins in diets. Proteins are obtained from meat, fish, and leguminous vegetables (beans, peas, etc.). Their use in the body is shown in the table.

Body building foods

Source of protein: beef

Part of body	**Process**
Mouth	Mastication by teeth. No digestion.
Stomach	Some proteins $\xrightarrow{\text{PEPSIN}}$ peptones
Duodenum	All proteins $\xrightarrow{\text{TRYPSIN}}$ peptones
Small intestine	Peptones $\xrightarrow{\text{EREPSIN}}$ amino-acids
Villi	Amino-acids absorbed into blood capillaries, carried by the hepatic portal vein to the liver.
Liver	Some amino-acids $\longrightarrow$ glucose and urea (deamination). Some amino-acids carried by blood to body cells. Glucose $\longrightarrow$ glycogen and stored, reconverted when necessary. Concentration of amino-acids kept constant in plasma.
Capillaries	Lymph carries amino-acids to body cells.
Cells	Amino-acids $\xrightarrow{\text{ENERGY}}$ proteins in protoplasm.
Kidneys	Excess urea removed, so that concentration of urea in plasma is kept constant.

Enzymes are proteins, and amino-acids in cells are used to *synthesise* enzymes to catalyse chemical reactions taking place in cells and in living processes.

Fats

FORMATION OF FATS

Fats are not formed by photosynthesis in plants; they are built up from carbohydrates. All fats contain carbon, hydrogen and oxygen, but not in the same proportions as in carbohydrates. Fats are a compound of **glycerol** and a **fatty acid**; different fatty acids produce different fats and oils.

Tests for fats

1 The fat is dissolved in petrol, and the solution poured on filter paper. When the petrol evaporates, a *grease-spot* is formed.

2 A dye, **Sudan III**, is added to fat, and a *red coloration* is produced.

Fats are digested to glycerol and fatty acids. These are absorbed into the lacteals of villi, and there recombine to form globules of fat. These globules are transported by lymph and passed into the blood stream to be transported to tissues, where they are deposited as fat cells, or used in tissue respiration in body cells. The fat is oxidised in the cell to carbon dioxide and water, and energy is released.

Fats in diet. Most fat is obtained from animal sources. A little is obtained from plant foods such as maize and beans.

Protective foods

HISTORICAL DISCOVERY

In the time when sailing ships made long voyages, the seamen, who fed on salted and dried food, fell sick with a disease called **scurvy**. On returning to land and eating fresh food, the disease was cured. If the sea voyage was very long, many of the seamen died. Captain **Cook**, in the 18th century, found that *lime juice*, given daily to the seamen, prevented scurvy. Experience of seamen, and other people feeding on preserved food, showed that green vegetables and fruit prevented scurvy.

In the East Indies, **Dr. Eijkman** investigated the disease of **beri-beri**. He found that chickens fed only on polished white rice developed beri-beri, but when fed on rice polishings (made from the outer husk of the grain), the chickens recovered. Here then were two diseases caused by a deficiency in diet.

Dr. Gowland Hopkins

Hopkins, an English chemist, was interested in diet. He knew the facts concerning scurvy and beri-beri, and also the fact that plenty of fat in the diet prevented the disease of **rickets**. He experimented with rats, and fed them on a synthetic diet of pure carbohydrate, pure protein, and purified fat, all prepared chemically. The rats lost weight and became ill. Rats fed on unpurified food, under the same conditions, gained weight and were healthy. Further experiments showed that (1) the addition of milk to the synthetic diet made the rats healthy again; (2) the synthetic diet caused loss of appetite. Hopkins concluded that normal food contained 'food accessory factors' necessary for the maintenance of health, and only very small amounts of these substances were needed in the diet.

In 1912, **Funk**, a Polish chemist, verified the existence of active substances, the 'food accessory factors', and named them **vitamins**. Subsequent work by many scientists drew up the present list of vitamins, which are know by letters.

Vitamin	Source	Deficiency disease	Solubility
A	Yellow and red vegetables. Green leaf vegetables. Fish liver oils. Eggs, milk, butter.	NIGHT BLINDNESS. Low resistance to germs. Dry and scaly skin.	Fat soluble
B_1	Outer husk of cereals.	BERI-BERI	Water soluble
B complex	Outer husk of cereals.	PELLAGRA. Skin disorders (dermatitis).	Water soluble
C	Fresh fruit. Fresh vegetables.	SCURVY, ANAEMIA.	Water soluble
D	Fish liver oils.	RICKETS. Dental decay	Fat soluble

Vitamin E is supposed to prevent *sterility* (i.e. inability to reproduce), and a deficiency of vitamin K delays the clotting of blood; neither of these two vitamins has yet been fully investigated.

Vitamins are essential parts of a diet; a serious lack causes the diseases listed above; a lesser deficiency undermines health. The diseases caused by lack of vitamins are called **deficiency diseases**; they are described below.

Night blindness. The retina of the eye is affected and vision is poor in dim light; a serious deficiency of vitamin A can cause permanent blindness.

Beri-beri. Vitamin B_1 controls the supply of glucose to muscles and nerve cells; the *symptoms* of beri-beri are loss of feeling in the legs, muscular cramp and pains. Severe deficiency can cause death.

Pellagra. The disease produces general weakness and disorders of the nervous system. The *signs* are skin rashes and sores, and diarrhoea.

Scurvy. The disease causes tender and bleeding gums, with teeth becoming loose and falling out in extreme cases. It causes general weakness.

Rickets. This is a disease which twists bones out of shape; it is mainly observed in children.

Vitamins in a diet

Only very small amounts of vitamins are required daily to prevent deficiency diseases. The following table shows the daily requirements of vitamin sources.

Daily vitamin requirements	
A	1½ oz. liver OR 2 oz. chilis OR 5 oz. butter OR 12 oz. cabbage.
B	6 oz. dhall OR 10 oz. brown bread OR 10 oz. half-milled rice.
C	2 oranges OR 3 mangoes OR 4 bananas OR 3 oz. papaya.
D	1½ oz. liver OR 1½ oz. fish.

Other food requirements

COMMON SALT, SODIUM CHLORIDE

Sodium chloride is one of the substances dissolved in plasma; it is excreted during sweating; it is used to make hydrochloric acid secreted by the glands in the stomach walls; it is necessary for the action of ptyalin; it also aids the working of muscles. For normal purposes, about 15 grams of salt is needed per day; excessive sweating, due to heavy exercise, or hot conditions, necessitates a greater intake.

CALCIUM SALTS

Bone contains calcium phosphate; teeth also use calcium salts to make dentine and ivory. Calcium salts are found in the husks of cereals and the outer layers of vegetables and fruits. Children, with growing bones and teeth. need twice as much calcium as adults. The daily requirement of calcium is provided by 1½ lb. of beans *or* 1¼ pints of milk *or* 3 oz. cheese. Lack of dairy products in tropical countries often causes calcium deficiencies.

IRON

Iron salts are needed to make haemoglobin. Lack of iron causes **anaemia**, which is a condition of insufficient red corpuscles in the blood. Beans, figs, and tamarind supply iron, and 4 oz. of either per day is sufficient to provide iron in the diet.

IODINE

Iodine is used by the thyroid gland in its secretions. Lack of iodine causes the disease **goitre**. Sufficient iodine is usually obtained from common salt, in which iodine is an impurity.

PHOSPHORUS

This element is needed in the formation of bones (see calcium). Phosphorus also plays an important part in the working of muscles. Only about 1 gram per day is needed, and this is normally available in beans, meat, and fish.

WATER

The need for an intake of water to keep the concentration of soluble substances in plasma at the correct level has been discussed under the circulatory system. Water is lost from the body by (1) urination (2) sweating (3) expiration of air (4) defaecation. The intake must balance the losses.

Diets

REQUIREMENTS OF A DIET

The body needs (1) carbohydrates and fats to provide energy; (2) proteins for body building; (3) vitamins for protection; (4) mineral salts and water for the functioning of the body.

ENERGY PROVIDING FOODS

Heat energy is measured in **calories**. 1 calorie is the amount of heat which will raise the temperature of 1 gram of water by 1°C. As the calorie is a small unit, the Kilo-calorie (= 1,000 calories) is used; it is called a Calorie (capital C). The energy provided by foodstuffs is measured in Calories. 1 gram of carbohydrate or 1 gram of protein releases 4 Calories, while 1 gram of fat releases 9 Calories of heat. The daily requirement of energy varies with the weight of a person. For average adults, the daily requirements for different occupations are shown in fig. 3.1. The daily requirement must be met from carbohydrates, proteins and fats.

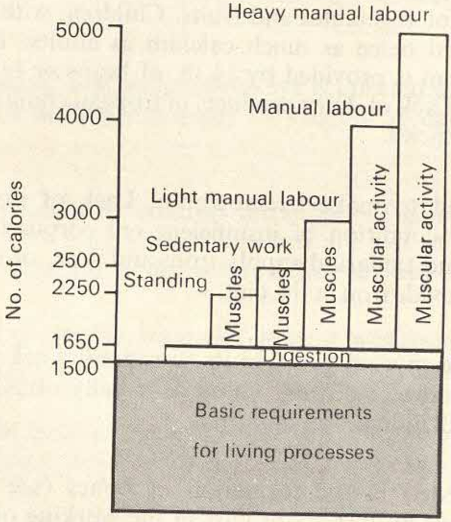


fig. 3.1 Daily requirements of energy

BODY BUILDING FOODS

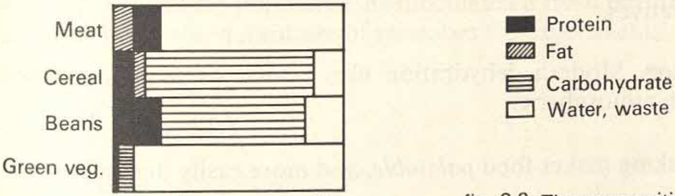
Too much protein is difficult to digest in tropical countries. Protein should provide about 10% of the daily energy requirement, i.e. about 80–100 grams of protein is needed. Half the quantity should be *animal protein* and half should be *vegetable protein*. These differ in the proportions of the amino-acids constituting their molecules.

OTHER REQUIREMENTS

The foods eaten must meet the requirements of vitamins for protection, and mineral salts for body functions.

BALANCED DIETS

Cereals (rice, wheat, maize) provide most of the carbohydrates; meat, fish and leguminous vegetables the protein. Each food, however, usually provides foodstuffs other than its basic constituent, although in smaller quantities. The basic composition of common types of food is shown in fig. 3.2. Observe that eating 10 oz. of meat does not provide 10 oz. protein, but approximately 1 oz. protein only, as there is water and waste in all foods.



Approximate composition

fig. 3.2 The composition of foods

Appetite. Hopkins's work showed that a varied diet was necessary to stimulate appetite. Without appetite, the full value of food is not assimilated, as digestion is less efficient. A further demand for a balanced diet is, then, a varied diet.

Food	Carbo-hydrates	Fats	Proteins	Calories	Vitamins	Minerals
¼ lb. beef	—	40 g.	10 g.	400	B_1	Phosphorus
2 oz. beans	65 g.	4 g.	10 g.	350	B	R Iron
1 oz. butter	—	22 g.	—	200	A, D	—
20 oz. rice	500 g.	5 g.	40 g.	2200	B	—
24 oz. green vegetables	16 g.	—	8 g.	100	A	Calcium
8 oz. fruit	25 g.	—	2 g.	100	C	—
Total	606 g.	71 g.	70 g.	3350	—	—

Notes on the diet

1 The number of grams of vegetable and animal protein are the same.

2 The number of grams of protein is nearly 80 grams.

3 Protein provides just under 10% of the total number of Calories (280 Calories).

4 All vitamins are present.
5 Only salt has to be added (to give iodine as well), and all the essential mineral salts are present.

Food preservation

Drying. Food is dried in the sun, or smoked; this causes *dehydration*.

Pickling. Food is pickled in vinegar or in brine (i.e. salt solution). This also removes water from the food. *Preserving* with sugar has the same effect.

Sterilisation. Food is heated to about 250°C. to kill bacteria, and placed in a container while still warm. Iron cans covered in tin ('tin cans') are used as containers.

Freezing. Cold reduces baterial activity, so food is kept in refrigerators for short periods of time, or in cold storage for longer periods.

Chemical preservation. Sulphur dioxide and benzoic acid are added as preservatives.

Dehydration. Modern dehydration uses heated ovens at a pressure lower than atmospheric.

Uses. Cooking makes food *palatable*, and more easily digested.

Boiling. Vitamins B and C, being water soluble, are removed, and destroyed by heat. Longer boiling destroys vitamin A.

Frying. This makes food less digestible, and hence more satisfying. Vitamins A and D, being fat soluble, are removed and destroyed.

Roasting or baking. These are preferable methods, as they lessen the losses in vitamins.

Cooking rice. Milled rice, i.e. polished or white rice, has its vitamin B removed; boiling in water removes more of the vitamin. The best method of cooking rice is steaming it.

Cooking meat. Boiling meat removes most of the mineral salts; frying makes it more indigestible; roasting is preferable as losses are kept low. Tinned meat has lost a good part of its nutritional value, due to boiling before canning.

4 The germ theory of disease

Historical introduction

LEEUWENHOEK

A Dutch tradesman, Leeuwenhoek, made a hobby of grinding lenses, and with them made the first microscope, the first essential to a study of bacteria. He discovered *microscopic* forms of life in rain water, and also in scrapings from his teeth. Although not then recognised as such, Leeuwenhoek had discovered bacteria. He also laid a foundation for accurate experimental work as the basis of knowledge.

PASTEUR

Pasteur was a French chemist who investigated the problem of why some wines did not ferment properly. While studying the yeast that caused the fermentation, he discovered, with his microscope, small rod-shaped microscopic forms of life, these were called microbes. He transferred microbes, by a needle, to a *sterile* soup he invented (called inoculating the soup) and the microbes reproduced; when the soup was thickly populated, he inoculated a fresh portion of soup, and thus maintained a **culture** of microbes for experiments.

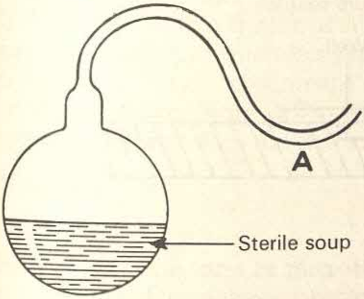


fig. 4.1 Pasteur's flask

Dispersion of microbes

Pasteur made glass flasks of the shape shown in fig. 4.1. He boiled soup in them, to make it sterile, and allowed the flasks to cool. No microbes appeared in the soup. He then tipped the flasks to leave some soup in the neck at the point marked A in fig. 4.1. Microbes appeared at point A, but did not go up the neck of the flask. He thus demonstrated that microbes are carried by air. By conducting experiments in cellars, up mountains, and in dusty farmyards, he showed that only dusty air contained microbes.

Microbes cause disease

Pasteur investigated diseased silkworms, and found tiny microbes in them. He showed that the microbes reproduced, and when in sufficient numbers, caused disease. The causes of disease were now known for the first time.

LISTER

In the 19th century about 50% of all *surgical operations* resulted in the death of the patient, due to the wounds becoming septic (i.e. forming quantities of pus). Lister, an English surgeon, realised that dirt probably caused the septic wounds. His first attempt to reduce the number of deaths by cleaning the hospitals, the clothes of the surgeon and the patient, and the operating instruments, had only a small effect. Lister read of Pasteur's experiments, and thought microbes might be the cause of suppuration (i.e. pus formation). He experimented with *carbolic acid*, a disinfectant used to kill microbes in sewage. He applied dressings soaked in carbolic acid to surgical wounds, and as a result of his experiments the death rate fell to 15%. Lister invented **antiseptic** surgery, in which any microbes in the wounds are killed by disinfectants. Later developments led to **aseptic** surgery, where microbes are excluded from the operating theatre, and prevented from reaching the wound. **Antisepsis** and **asepsis** are used together in modern surgery.

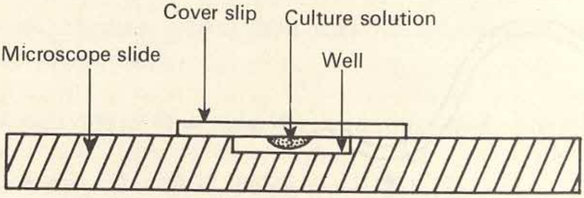


fig. 4.2 Koch's slides

KOCH

Koch, a German doctor, investigated the disease in cattle called **anthrax**. With his microscope, he identified rod-shaped microbes present in the blood of diseased animals. He transferred some microbes to a cut beneath a mouse's tail. The mouse died of anthrax, so he had found the cause. To show that microbes were alive and capable of reproduction, he ground a well in a microscopic slide (see fig. 4.2), put a culture solution containing anthrax microbes on a coverslip, and inverted the slide. The hanging drop ensured that only anthrax microbes were in the culture. Observations showed that the microbes reproduced, and these microbes were used to inoculate mice, which then developed anthrax. Koch showed that anthrax was caused by a specific microbe, and the microbes were alive and capable of reproduction; he also showed that heat caused the microbes to form **spores**, by which means they were dispersed.

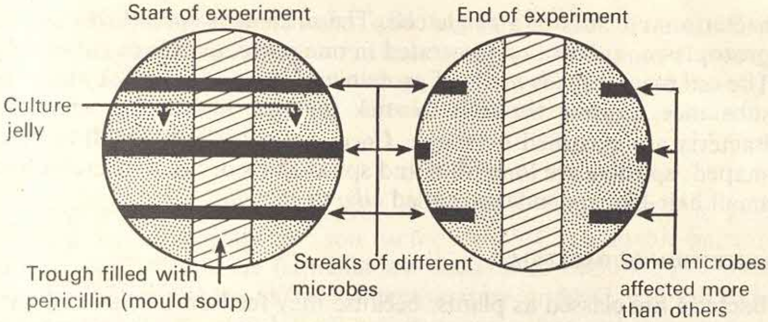

Start of experiment
End of experiment
Culture jelly
Trough filled with penicillin (mould soup)
Streaks of different microbes
Some microbes affected more than others

fig. 4.3 Fleming's experiment on penicillin

FLEMING

Before 1940, the drugs used as medicines were naturally occuring products, such as quinine, or chemicals such as salvarsan; these compounds actually killed microbes; too much of the drug could kill the patient as well. Fleming, a Scottish biologist, was investigating the microbes causing boils; he cultured them in soup, made from agar, contained in flat dishes. One dish, left uncovered, was infected by spores of a mould. Fleming observed that the mould killed some microbes. The mould was identified as *Penicillium notatum*, similar to the blue mould on cheese. He set up the experiment shown in fig. 4.3. Culture jelly, with a trough filled with soup made from the mould, had streaks of different microbes placed across it. The mould soup killed the microbes. This experiment led to the discovery of *penicillin*, an *antibiotic*. An antibiotic differs from a drug, in that it prevents microbes reproducing, but does not actually kill them.

Bacteria

STRUCTURE

Bacteria are one form of microbe. They are so small that they can be seen only under a microscope; many are about $\frac{1}{1000}$ mm. long. Each

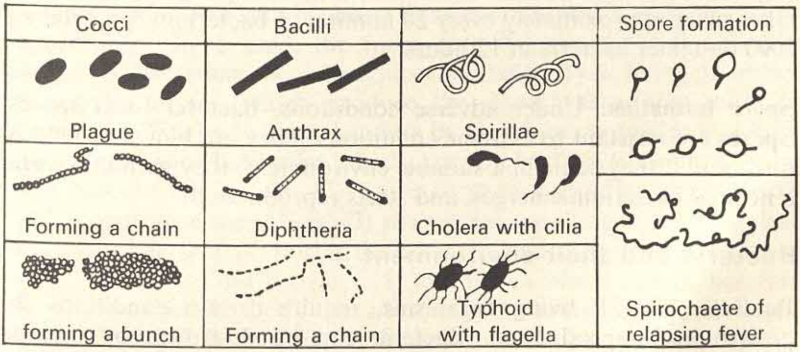


fig. 4.4 Types of bacteria

bacterium consists of a single cell. The nucleus is spread through the protoplasm, and not concentrated in one place, as it is in entamoeba. The cell membrane is made of protein and it excretes a sticky jelly-like substance, causing the cells to stick together in bunches or chains. Bacteria are classified by shape. **Cocci** are spherical; **bacilli** are rod-shaped; **spirillae** are long, thin and spiral-shaped. Some bacteria have small hair-like appendages, called *cilia* or *flagella*.

NUTRITION OF BACTERIA

Bacteria are classed as plants, because they feed on liquids and gases and do not digest solid particles (compare amoeba). They do not possess chlorophyll, so they are either parasites or saprophytes. Disease-causing bacteria are parasites. Bacteria excrete enzymes which digest the tissues of the host; the products are absorbed and energy released by respiration. This is external digestion. The action of bacteria on carbohydrates is called **fermentation**; on proteins it is called **putrefaction**.

RESPIRATION IN BACTERIA

Both **aerobic** and **anaerobic** respiration is used by bacteria (compare yeast). Each species of bacterium produces a single change, and a whole chain of different bacteria is needed to break down cellulose, or carbohydrates to carbon dioxide and water.

EXCRETION IN BACTERIA

The end products of nutrition and respiration are excreted from the cell. These products are the **toxins** which cause disease in the host, in the case of parasitic bacteria; other bacteria in the host are harmless, as their excretory products are not *toxic*.

REPRODUCTION OF BACTERIA

Reproduction is asexual by division into two daughter cells. Division takes place approximately every 20 minutes; 1 bacterium can produce 5000 daughter bacteria in 12 hours.

Spore formation. Under adverse conditions, bacteria form spores. **Spores** are resistant to extreme conditions. They are blown around in dust, and if they settle in a suitable environment, they germinate, and a normal bacterium emerges, and starts reproduction.

Bacteria and their environment

Bacteria, like all living organisms, require certain conditions for growth and reproduction. Bacteria can be destroyed by making conditions unsuitable for their living processes.

1 Water. Bacteria require water, and the water content of dust, soil, or other environment determines bacterial activity. Different percentage of water contents have the following effect: under 3 % – no activity; 4-5 % – activity starts; 25-40 % – ideal conditions.
Spores withstand dryness.

2 Temperature. Different species of bacteria have different ideal temperatures. Examples are: soil bacteria at 25° C.; parasitic bacteria in man at 37° C.; some fermentation bacteria at 70-80° C. For most bacteria, activity stops at 0°C. A temperature of 50°C. will kill most bacteria; of 100°C. will kill all active bacteria, but not their spores; of 120°C. will kill spores as well. Notice cold does not kill bacteria, only makes them inactive.

3 Light. Bright light makes bacteria inactive; direct sunlight kills them. Darkness or feeble light encourages activity.

4 Oxygen. Aerobic bacteria require oxygen; a lack of oxygen kills them. Anaerobic bacteria do not require oxygen.

5 Chemicals. Some bacteria require an acid solution, but the majority require an alkaline solution for activity. Chemicals that kill bacteria are used as **antiseptics**.

6 Antibiotics. These drugs stop bacterial reproduction, and allow parasitic bacteria to be attacked by white corpuscles, and removed from the body.

LIFE HISTORY OF PARASITIC BACTERIA

A **spore** settles on a suitable host; if the environment is suitable (water, temperature, light, etc.), the spore germinates and forms an **active stage**. The **bacterium** then reproduces asexually. By its living processes, it excretes **toxins**, which produce the disease associated with the bacterium. The body fights bacteria by (1) white corpuscles and body tissues producing **antibodies**, which cause the bacteria to clump together and become less active; (2) white corpuscles producing **antitoxins**, which neutralise the toxins; (3) **phagocytes** engulfing and eating dead and living bacteria; (4) raising the body temperature to reduce bacterial activity. Medical aid provides (1) antibiotics which reduce bacterial activity so that the body can overcome the remaining bacteria; (2) drugs which kill the bacteria. If the host dies, the bacteria form spores, ready to be dispersed to the next host.

Harmful bacteria are those that cause disease in human beings, animals, and plants. All such bacteria are **parasites**, as they use a living host to obtain their food supply.

Useful bacteria. These outnumber harmful bacteria. The soil contains many thousands of bacteria per cubic centimetre of soil. Putrifying bacteria cause protein in dead plants and animals to turn to ammonia; different bacteria change ammonia, by stages, into nitrates, ready to be absorbed by plants to make fresh protein. Carbohydrates are similarly changed by a succession of bacteria, to carbon dioxide and water. Soil bacteria are thus useful agents of change and decay. Man also uses bacteria to ripen cheese, cure tobacco, form vinegar, and for many other uses as well.

Harmless bacteria. Simple examples are the harmless bacteria in the human large intestine. Some of these are a species of *entamoeba*, similar to *entamoeba hystolytica*. They have no effect, either adverse, or beneficial, on the body.

Personal health and hygiene

ENTRY OF GERMS

Spores of bacteria, and other forms of harmful germs, are plentiful in dust and dirt. (Germs are microbes causing illness.) Germs gain entry to the body in the following ways: (1) through the mouth; (2) through the nose; (3) through wounds or cuts; (4) in some cases, through the skin. The entry of germs can be kept to a minimum by personal cleanliness.

PERSONAL CLEANLINESS

Cleanliness means absence of dirt; *hygiene* means health, and implies the absence of germs. Hygienic conditions imply a greater degree of cleanliness than just clean.

1 The hands. Sweat and oily secretions from the hands are excellent breeding places for germs. Finger nails harbour dirt, and, correspondingly, germs. Hands and finger nails must be kept clean to avoid the transference of germs during eating. Scratching transfers germs, particularly those of *fungal diseases*, and intestinal worms. Clean hands are essential for food preparation.

2 The feet. *Fungal diseases* breed between the toes, especially when the skin sweats. **Hookworm** can enter the skin of the feet if shoes are not worn. Light, open, shoes avoid both diseases being caught. Well-fitting shoes are necessary to avoid cramping toes and causing a bad posture through deformed feet.

3 The skin. Sweat and oily secretions from the skin block pores and cause dust (carrying bacteria) to stick to the skin. Blocked pores reduce the ability of the skin to carry out its normal functions. Warm water and soap is needed to keep the skin clean. Bathing should not be carried out after heavy meals, or immediately after heavy exercise. Bathing causes blood to be drawn to the skin, and thus can interfere with other body functions. Fresh air and sunlight are beneficial to the skin; excessive exposure to sunlight burns and destroys skin tissues. Skin hygiene also avoids parasites such as **fleas**, **scabies mites** and **lice**.

4 The mouth and teeth. Very hot and very cold foods should be avoided as they cause the *enamel* of teeth to chip. Teeth should be cleaned, and the mouth rinsed, after every meal, otherwise food particles cause tooth decay. Vigorous brushing of the teeth causes wear; soft tooth brushes should be used with an up-and-down motion. Decayed teeth lead to bad *mastication*, and they also discharge poison into the digestive system. Calcium and phosphorus are essentials in a diet for strong and healthy teeth. Teeth should be evenly spread, to avoid decay; milk and permanent teeth should be removed, on dental advice, to ensure even spacing. Teeth should be given sufficient exercise by including hard fibrous food in the diet; such a diet also encourages a flow of saliva. A hard deposit, called *tartar*, often accumulates at the back of teeth, particularly incisors; it is a mixture of calcium phosphate and calcium carbonate, and is caused by excessive production of saliva. Tartar should always be removed by a dentist, otherwise the gums will recede, exposing the *dentine*. Teeth should be inspected every 6 months. Cavities quickly accumulate food particles and cause decay; early filling of cavities prevents loss of the tooth. Dental decay decreases with age, but regular dental visits are still advisable.

5 The head, nose, and ears. The scalp and hair need frequent washing to avoid the growth of parasites such as **lice**, which communicate diseases, and to avoid fungal infections such as **ringworm**. The nose contains hairs which remove dust (and bacteria) from the air breathed in. Frequent blowing is advisable to remove accumulated dust. Breathing through the mouth is not recommended, as dust is not filtered out, and spores of bacteria, or germs, settle on the *mucous* lining of the pharynx, and infections can start from there. Care should be taken of the ears to prevent infection entering and breaking the *ear-drum*. *Fungal infections* of the ears are common in the tropics, and frequent cleaning is necessary to avoid fungal spores settling and germinating. Loud noises, and blows on the ear, can also rupture the ear-drum; a ruptured ear-drum allows infection to develop in the middle ear. Ears should be cleaned of excessive wax by a doctor or nurse using a syringe.

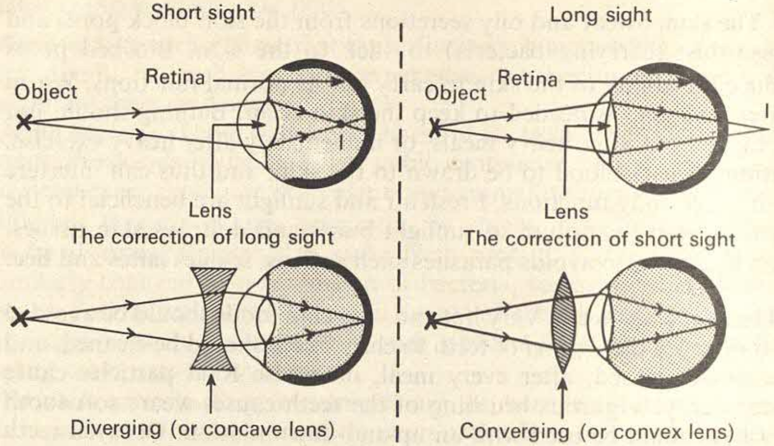

Short sight
Long sight
Object
Retina
Lens
I
Object
Retina
Lens
I
The correction of long sight
The correction of short sight
Diverging (or concave lens)
Converging (or convex lens)

fig. 4.5 Defects of sight

6 The eyes. Eyes should be kept clean by bathing with water, especially where flies are a menace. Tears are antiseptic and help to keep bacterial infection to a minimum. Eye-strain should be avoided by using a good light for reading. If the sight is poor, spectacles are needed. The defects of the eye are **long sight** and **short sight**. In long sight, the eyeball is too short, and the image (I in fig. 4.5) is formed *behind* the retina. This defect is corrected by using a converging (or convex) lens, which focuses the image on the retina. In short sight, the eyeball is too long, and the image is formed *in front of* the retina. This defect is corrected by using a diverging (or concave) lens, focusing the image on the retina. Another defect of the eyes is **astigmatism**, in which the focus of the eyes is different for vertical and horizontal lines; special lenses are needed in spectacles to correct this defect. Defects cause eye-strain, and headaches; spectacles should always be worn to correct eye defects.

7 Clothing. Light clothing should be worn in the tropics to give protection against the sun; the clothes should be white or of a light colour, as these are cooler than black or dark coloured clothes. The clothes should be loose-fitting to allow air to circulate so that sweat can evaporate. The order of coolness of different fabrics is: linen, cotton, silk, artificial silk, nylon, and wool (the warmest). Clothes saturated with sweat irritate the skin, and infections can then enter. All clothes should be changed frequently and washed thoroughly with soap and water; they should be dried on a line (not on the ground) and ironed with a hot iron to kill any remaining sources of infection. *Fungal diseases*, such as **dhobi's itch**, are spread by dirty water used for washing; clothes should be aired to prevent the growth of moulds, which cause skin irritation.

CLEANING MATERIALS

Soap, detergents, antiseptics, and disinfectants are used as cleaning materials. *Soap* and water remove dirt, and hence many bacteria. *Detergents* are modern replacements for soap. *Antiseptics* are used to prevent infection of cuts and wounds; they are mild in action. *Disinfectants* are cruder and cheaper chemicals than antiseptics; they are used to kill bacteria. Common antiseptics are: potassium permanganate; hydrogen peroxide; acriflavin. Common disinfectants include: chloride of lime; coal tar preparations (carbolic acid and cresol).

HYGIENE OF THE BODY

Cleanliness and a balanced diet are the basis of hygiene. **Exercise** improves the muscles, so they support the body correctly. It quickens blood circulation, and breathing; this helps to remove waste products and *toxic* substances; it improves the digestive system as a result.

Posture. Good and bad postures are shown in fig. 4.6. Bad posture hinders breathing, and peristalsis, by cramping the chest and abdominal cavities. Good posture should become a habit.

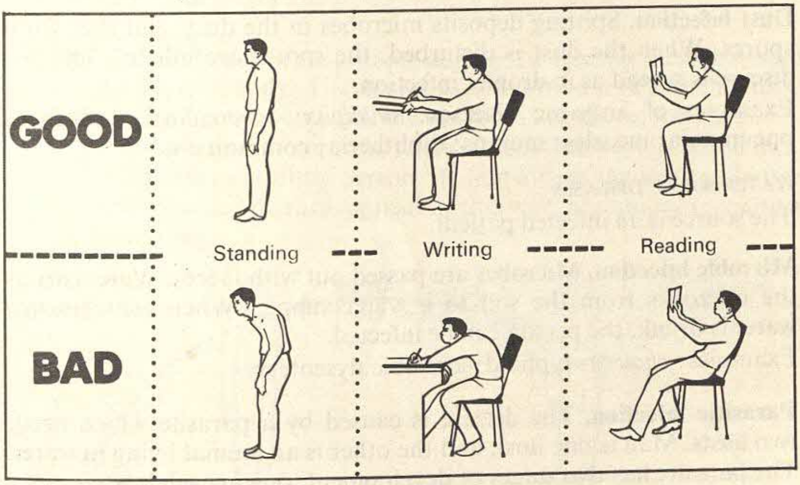


fig. 4.6 Good and bad posture

Sleep and recreation. Sleep is needed to allow the body to rest in order to make good the wastage taking place during activity. Children need 12 hours sleep, and adults 7–8 hours sleep, a day. A dark, cool, and well-ventilated room is essential for sound sleep. Recreation should provide relief from any form of monotonous work; it keeps the brain active, and the nervous system in good order. Varied recreation is needed for a person to enjoy mental health. Full physical health is not possible without mental health.

5 The spread of disease

The four considerations associated with a disease are:

1 **The vector** – means by which the disease is spread.
2 **The causative agent** – parasite (or germ) which causes the disease.
3 **The symptoms** – the effects of the disease (the *signs* are the visible effects of the disease).
4 **Prophylaxis** – methods used to prevent and control the spread of diseases.

Disease vectors

AIRBORNE DISEASES

The source of infection is a patient suffering from the disease; disease microbes are present in the patient's saliva.

Droplet infection. When the patient sneezes, coughs, or breathes deeply, microbes are blown, with saliva, into the air. People within a distance of 10 feet inhale the microbes. If a person's resistance is low, he becomes infected.

Dust infection. Spitting deposits microbes in the dust, and they form spores. When the dust is disturbed, the spores are inhaled, and the disease is spread as in droplet infection.
Examples of airborne diseases: *smallpox*; *tuberculosis*; influenza; pneumonia; measles; mumps; diphtheria; common cold.

WATERBORNE DISEASES

The source is an infected patient.

Microbic infection. Microbes are passed out with faeces. Water carries the microbes from the soil to a water supply. When *contaminated* water is drunk, the person can be infected.
Examples: *cholera*; typhoid; amoebic dysentery.

Parasitic infection. The disease is caused by a parasite which needs two **hosts**. Man is one host, and the other is an animal living in water. The parasite has two stages of development, one in each host.
Examples: *bilharziasis*; liver flukes; Guinea worm.

CONTACT DISEASES

The source is an infected person.

Microbe or spore infection. Direct skin contact transfers microbes or spores from an infected person. Some microbes can only enter through a wound or cut in the skin, others attack and enter the skin.
Examples: *tinea* (ringworm); leprosy; yaws. (**Contagious diseases**).

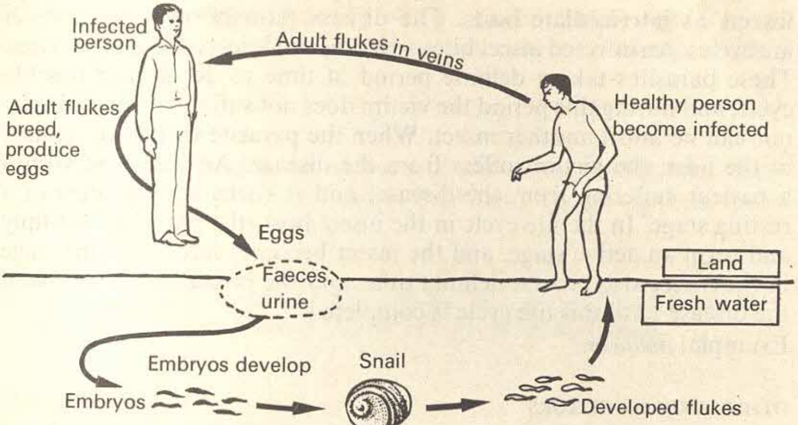


fig. 5.1 Bilharziasis

Parasitic infection. Small animal parasites are transferred by direct skin contact, e.g. fleas, lice, ticks, mites. Diseases spread by these animals are discussed under animal vectors.

INSECT-BORNE DISEASES

Insects as carriers

1 The insect feeds on faeces and during the feeding microbes stick to its feet and body. The microbes are carried away by the insect, and when it settles on food, the microbes are left on the food.

2 The insect bites a victim, and takes in microbes with its blood meal. When it bites a healthy person, its bite infects the victim. Sources of infection, for diseases spread in this way, are animals as well as human beings.

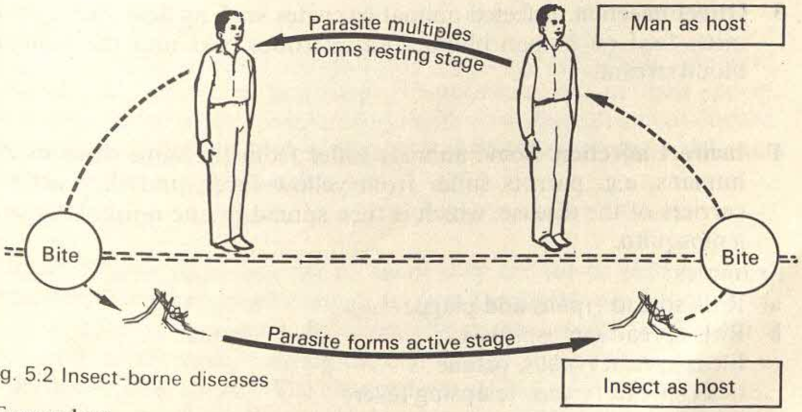

Parasite multiples forms resting stage
Man as host
Bite
Bite
Parasite forms active stage
Insect as host

fig. 5.2 Insect-borne diseases

Examples:

1 *cholera*, typhoid, bacillary dysentery, amoebic dysentery.

2 yellow fever, dengue, sand-fly fever, sleeping sickness.

Insects as intermediate hosts. The disease parasite has two distinct life cycles. An infected insect bites a victim, and injects disease parasites. These parasites take a definite period of time to develop in this life cycle, and during this period the victim does not suffer from the disease nor can he infect another insect. When the parasite is fully developed in the host, the victim suffers from the disease. An insect now bites a patient suffering from the disease, and it sucks up parasites in a resting stage. In the life cycle in the insect host, the parasites multiply and form an active stage, and the insect becomes infected. This stage in the insect also takes a definite time, and the insect cannot transmit the disease until this life cycle is completed.
Example: *malaria*.

OTHER ANIMAL VECTORS

Animals can spread diseases by (1) acting as hosts to infected animal parasites, or (2) being themselves infected and contaminating food and water supplies, or (3) being themselves infected and infecting other vectors.

1 **Hosts to parasites.** The rat harbours fleas, ticks, and mites. These animal parasites are transferred to human beings. The parasites can carry disease.

2 **Contamination of food and water.** The rat passes out microbes in urine and faeces, contaminating water or places where it feeds.

3 **Direct infection.** Infected animal parasites such as fleas, ticks, and mites feed on human blood, and microbes pass into the human blood stream.

4 **Indirect infection.** Some animals suffer from the same diseases as humans, e.g. parrots suffer from yellow fever, and they act as carriers of the disease, which is then spread by the normal vector, a mosquito.

Examples:

a Rats spread *typhus* and plague.
b Rats spread leptospirosis.
c Fleas spread *typhus*, plague;
ticks spread *typhus*, relapsing fever;
mites spread *typhus*.
d Game animals and cattle spread sleeping sickness;
snails spread flukes and *bilharziasis*.

FOOD CONTAMINATION

The other vectors, mentioned above, can take part in this method of spreading disease.

1 **Direct contamination.** Microbes in faeces are carried by flies, dirty hands, or 'night soil' on crops. Intestinal diseases are the main diseases spread in this way.

2 **Worm cysts.** If meat and fish are not well cooked, any cysts they may contain can develop into worms in the human body.

Examples:
a typhoid, *cholera*, dysentery;
b tapeworms, roundworms, liver flukes. Notice that diseases in (1) can also be water-borne and insect-borne.

3 **Infected animals.** Cooking meat kills any microbes that may infect it, but the toxins remain, and can cause 'food poisoning', an illness similar to typhoid.

4 **Decayed food.** During the decay of food, microbes breed in it, and are the cause of a disease called 'botulism'. The source of this illness is usually 'blown' tins.

CAUSATIVE AGENTS

The organisms causing diseases are: viruses, rickettsiae, bacteria, spirochaetes, protozoa, and fungi. These organisms, or their spores, have been called germs, or microbes, in previous descriptions of disease. Worms are usually added to this list of causative agents, although they do not cause specific diseases.

Viruses. These organisms are so small they cannot be seen by a microscope. They are small enough to pass through a sandstone filter. Viruses cannot reproduce by themselves; they attack and enter a living cell in the host, causing the cell to change its function, and to reproduce more viruses. The changed nutritional processes of the cell produce excretory products which are toxic. These toxins cause the specific diseases for which the virus is the causative agent.
Examples: *smallpox*, influenza, yellow fever, dengue, common cold.

Rickettsiae. These organisms are slightly larger than viruses, but still cannot be seen under a microscope; they can pass through a sandstone filter. Their methods of reproduction and of causing diseases are the same as for viruses.

Example: *typhus*.

Bacteria. Bacteria are large enough to be seen in a microscope; they are removed by a sandstone filter. (See p.56 for life processes.)

(*Examples of diseases caused by bacteria*) *cholera*, plague, bacillary dysentery, *tuberculosis*, typhoid, leprosy, tetanus, pneumonia, anthrax, septic wounds, boils.

Spirochaetes. These are spiral-shaped bacteria, larger in size than most bacteria.

Examples of diseases they cause: yaws, leptospirosis, syphilis.

Protozoa. These organisms are much larger than bacteria; they are *unicellular* animals with a nucleus. They reproduce asexually by division, and they can form special resting stages, or they can form spores. Destructive feeding by protozoa damages tissues in human beings, and their nutritional processes can release toxins. They cause specific diseases.

Examples: *malaria*, sleeping sickness, amoebic dysentery.

Fungi. Fungi are plants that spread by releasing spores (see p.6). Fungi mainly attack skin, and can cover a large area. The parasitic feeding of the plant lowers resistance to disease in the patient, and provides entry points for other microbes. Fungi cause specific diseases.

Examples: *tinea* (ringworm), athlete's foot.

Worms. Parasitic worms vary in length from $\frac{1}{4}$ inch to several feet. Some reproduce sexually and others asexually. Worms form eggs, which change into **cysts** to withstand adverse conditions. Parasitic feeding lowers the host's resistance to disease, and he is likely to suffer from other infections. Worms do not cause specific diseases.

Examples of worm infestations: *hookworm*, threadworm, roundworm. tapeworm.

Tropical diseases

SMALLPOX

Transmission of the disease. Viruses are the *causative agents* of smallpox; some viruses produce a more *virulent* (i.e. very strong) attack than others. The *vector* is droplet infection; the range of the droplets is 6 to 10 feet from an infected person.

The disease. After infection, the viruses take 10 – 14 days to develop, before symptoms of the disease appear. This is the **period of incubation**; during this period the person can infect other people, but is not aware he is suffering from smallpox. The disease begins with a fever and headache; a rash of red spots (called *nodules*) appear. The nodules enlarge and after 7 days become filled with pus. When the nodules burst, pus and viruses are discharged. If the viruses find contact with an open wound, they can infect another person by *skin contact*. If the patient recovers, the nodules dry up, form scabs, and leave *pock marks*. With heavy infections, the patient dies.

Cure and prevention. There are no known drugs to cure smallpox or any other virus-caused disease. Good nursing allows the patient to cure himself. General precautions include isolation of the patient. Prevention is by vaccination (p.82).

TUBERCULOSIS

Transmission of the disease. Bacteria (a bacillus) are the *causative agents*. The *vector* is droplet infection; the patient's saliva contains active bacteria, expelled during coughing. The bacteria form spores in dust, and the spread of the disease is helped by overcrowded and dirty housing conditions. Tuberculosis can also be transmitted by milk from infected cows; this is rare in the tropics.

The disease. Most people have the bacteria present in their bodies; many build up immunity by this contact. If a person's resistance is lowered (by malnutrition, or a chill), the bacteria develop and the person may suffer from the disease. The bacteria settle mainly in the lungs, and the patient coughs continuously. In later stages of the disease, blood is found in the saliva when the patient spits. The disease is diagnosed by X-rays of the lungs, which show dark patches. The final stages of the disease are wasting of the body, loss of weight, and finally death.

Cure and prevention. Drugs, such as streptomycin (an antibiotic), cure the disease in its early stages; the most effective cure is rest in well-ventilated conditions; the cure is always slow, and can be retarded by any mental anxieties. General precautions include isolating the patient and giving him separate eating utensils. Mass X-rays are useful for an early diagnosis, so the disease can be cured quickly in its early stages. Prevention is by vaccination using B.C.G. vaccine.

CHOLERA

Transmission of the disease. The *causative agent* is a comma-shaped bacterium, with a flagellum, which swims freely in water. The *vector* is water, contaminated by faeces, or flies carrying bacteria from faeces to food. Rivers and shallow wells are contaminated by water seepage from poor sanitary arrangements.

The disease. The *incubation period* is a few hours to 2 days. The patient has severe diarrhoea and vomiting; the stools lose their solid appearance and look like rice water. Cholera causes a patient to become rapidly dehydrated, and death usually occurs due to losses of fluid.

Cure and prevention. The intense dehydration is overcome by injecting saline (i.e. salt) solution into a vein. This allows the patient to fight the disease with a chance of recovery; drugs can also be administered to kill the bacteria. Prevention is by immunisation using an injection of cholera vaccine.

General precautions. Proper sanitary arrangements should be made, and all water should be filtered and boiled or chlorinated before use.

TINEA (RINGWORM)

Transmission of the disease. The *causative agent* is a fungus, spread by spores. The *vector* is skin contact, either with an infected person, or with a place infected with spores (e.g. clothing).

The disease. The fungal hyphae grow through the skin, and the fungus grows in the normal way. A small red patch on the skin gradually spreads. The patch causes intense itching; the fungus grows outward in a circular fashion (hence the name), darker at the edges, with the centre clear of the fungus. Ringworm of the scalp attacks hair, as well as skin; the hairs break off, leaving scaly patches of skin. The itchiness causes sleeplessness, and health is generally undermined.

Cure and prevention. Tinea is cured by the application of ointment. Prevention is by general cleanliness of the skin, and avoiding contact with infected people.

Historical introduction. In 1880 **Laveran** discovered the parasite which causes malaria. **Ross**, a doctor in the Indian Medical Service, set out to find the vector of malaria. **Manson** suggested mosquitoes carried the parasite. Ross's early work gave no results, as later experiments showed that only *anopheline* mosquitoes carried the parasite. Ross discovered parasites in the stomachs of female anopheline mosquitoes, and later traced the full development of the parasite in mosquitoes.

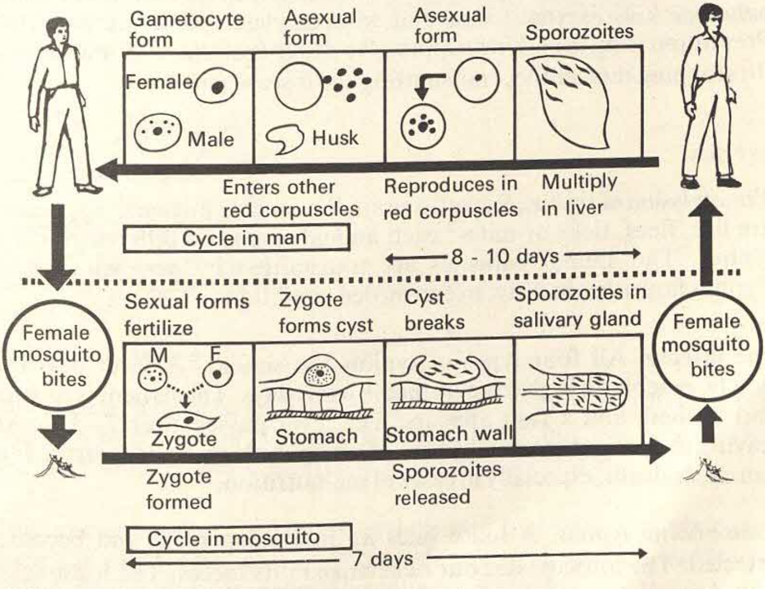
Transmission of malaria. An infected mosquito bites a victim and injects a protozoon, named *Plasmodium*. The disease is *insect-borne*.

The disease. The *incubation period* is 8 – 10 days. The patient has a rapid pulse, passes urine little in quantity and deeply coloured, and has a continuous fever, which is quickly followed by intermittent fever.

Types of malaria

1 *B.T. (benign tertian)*: a fever every 48 hours, is rarely fatal, and is liable to reoccur.
2 *M.T. (malignant tertian)*: a fever every 48 hours, is commonly fatal, and never reoccurs.
3 *Quartan*: a fever every 72 hours, is rarely fatal, and reoccurs frequently.

Each type of malaria is caused by a different species of plasmodium.



5.3 The malaria cycle

Malarial cycle. Plasmodium has separate life cycles in man and mosquitoes.

In man. Plasmodium *sporozoites* enter the blood stream from a mosquito's saliva, and pass to the liver. There they develop into asexual forms and multiply for 8–10 days (incubation period). They then enter the blood stream and attack red corpuscles. They feed on the corpuscles, reproduce asexually, leave the corpuscle husk and repeat the process in fresh red corpuscles. When the host's life is in danger, they form *gametocytes* (male and female forms).

In mosquito. Female anopheline mosquitoes suck in asexual forms and gametocytes with a blood meal. Only gametocytes develop; the male cells fertilise the female cells and a *zygote* is formed. The zygote forms a *cyst* on the stomach wall of the mosquito. The cyst develops and bursts, releasing *sporozoites* into the blood stream; the sporozoites are carried to the salivary glands, and are injected, in the saliva, when the mosquito bites a victim. It takes 7 days for the saliva to be infected. The excretory products of plasmodium are toxic; these toxins are released intermittently when the red corpuscles burst; this causes the intermittent fever. The asexual reproductive stage takes 48 or 72 hours, depending on the type of plasmodium. Reduction in red corpuscles causes anaemia, and eventually death.

Cure and prevention. Drugs cure the disease. *Quinine* kills asexual forms in the blood stream; *plasmoquin* kills gametocytes and sporozoites; *paludrine* kills asexual forms and gametocytes, and is the best cure. Prevention is by (a) taking suppressive drugs (paludrine or mepacrin); (b) stopping mosquitoes transmitting the disease (p.75).

TYPHUS

Transmission of typhus. Rickettsiae are the *causative agents*. The *vectors* are lice, fleas, ticks or mites; each animal spreads a different form of typhus. The animal parasites are transmitted by *personal contact.* Typhus flourishes in dirty, overcrowded conditions.

The disease. All four types of typhus are similar. A fever develops slowly, reaching a high temperature in a few days. The patient is bloated and flushed, and a rash appears. The fever passes after 2–3 weeks, leaving the patient extremely weak. During the high fever, heart failure can cause death, especially in cases of malnutrition.

Louse-borne typhus. A louse bites an infected person, and becomes infected. The louse passes out rickettsiae in its faeces. The louse takes blood meals from a victim and rickettsiae, deposited in faeces, enter the puncture in the skin. Rickettsiae can live for years in dust, and in this way infect a person who is free from lice.

Flea-borne typhus. Fleas from rats spread the disease. Typhus is a mild disease in rats, and infection is transmitted as with lice. The chain is: rat–flea–man. Flea-borne typhus can be spread by lice, and the chain is: rat–flea–man–louse–man.

Tick-borne typhus. This is spread by ticks on dogs or rats. Infection is the same as for louse-borne typhus. A small ulcer usually develops at the skin puncture.

Mite-borne typhus (scrub typhus). This is spread by mites on rats, and is common in the tropics. The mites have egg, larval, and adult stages. The larvae suck one blood meal, and may then become infected. The infected adult mite feeds on vegetation, produces eggs, from which larvae hatch out. These larvae are infected, and transmit the disease as by lice.

Tick-borne typhus is not spread by mites, nor mite-borne by ticks; neither form is spread by fleas and lice.

Cure and prevention. Antibiotics (chloromycetin and aureomycin) cure the disease. Prevention is by an injection of vaccine.

SCABIES

Causative agent. The scabies mite is very small; it burrows into the skin, and the surrounding skin is inflamed, forming a pimple. A small black mark ($\frac{1}{4}$ inch long) on top of the pimple is the burrow. The *vector* is personal contact.

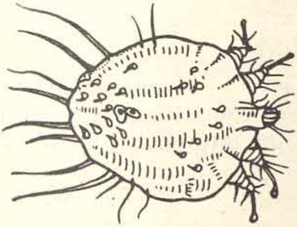


fig 5.4 A scabies mite

The disease. The pimples itch intensely, and continued scratching produces an infected sore. The mite lays eggs in the burrow, which hatch, and fresh mites come out to attack other parts of the skin.

Cure and prevention. The mites are removed by rubbing sulphur ointment (or other ointment) over the infected skin, and all clothes are boiled. Prevention is by general cleanliness of the skin.

BILHARZIASIS

Transmission of the disease. The disease is caused by a *fluke*, called bilharzia, which is a very small flat worm. The fluke is water-borne, and spread by an animal vector – the fresh water snail.

The bilharzia cycle. Adult flukes are very thin and about 1 inch in length. They live in veins near the intestines or near the bladder. Male and female worms are usually found in pairs. The female lays *eggs* with a sharp spine; the spine pierces tissues and the egg reaches the intestines or the bladder, and is passed out in either urine or faeces. The eggs hatch, in fresh water, into *embryos*, which infect fresh water snails, but not man. The embryos develop in the snail, and emerge as flukes with tails; the flukes must find a host within 1 – 2 days, or else they die. The host is either man, or other animals. Man is infected by either drinking, or standing in, infected water. The flukes enter through the skin, find their way to the blood stream, and settle down in veins. They develop and form *adult* male and female worms.

The disease. Flukes in the blood stream cause fever; as the infection increases, blood is passed in the urine. Chronic infection causes poor health and anaemia.

Cure and prevention. Biharziasis can be cured by intravenous injections of drugs. General precautions include avoiding infected water.

HOOKWORM

Causative agent. Hookworms are small, thin, round-shaped worms, about ½ inch long, and hang on the walls of the intestine by teeth (or hooks).

Hookworm cycle. Male worms fertilise female worms, which lay eggs. The eggs pass out with the faeces; the eggs hatch in warm moist soil, but sunlight kills them. Small larvae hatch from the eggs and feed on the faeces. In 4 – 5 days, these change to mobile larvae, which penetrate soft skin on the feet. The larvae pass through tissues to the blood stream, and then to the heart, and next the lungs. The larvae then pass up the trachea, into the throat, down the oesophagus, through the stomach to the small intestine. The larvae attach themselves to the intestinal walls, mature into adult forms, and repeat the cycle.

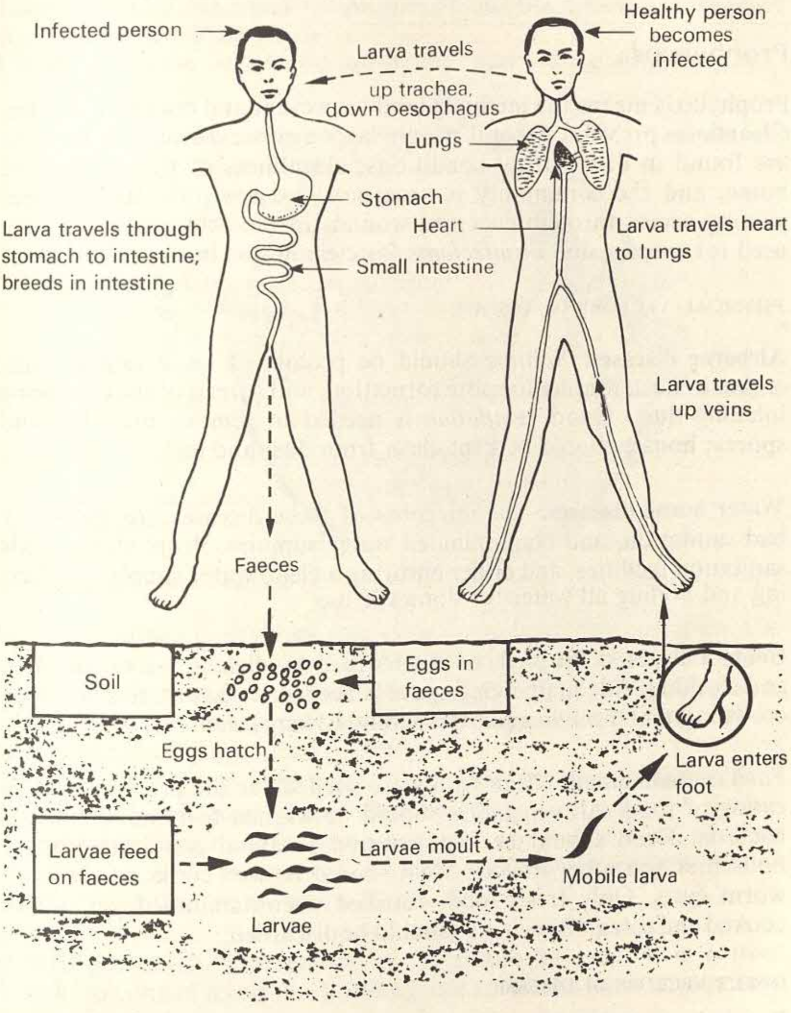


fig. 5.5 The hookworm cycle

The disease. Hookworm is actually an *infestation* of worms, and not a disease. The parasites cause ill health and anaemia. Death is caused by weakness or diarrhoea.

Cure and prevention. Drugs can be taken to kill the hookworms, and then they are passed out with the faeces. General precautions include the improvement of sanitation and the wearing of shoes, particularly in infected areas.

6 The conquest of disease

Prophylaxis

Prophylaxis means the methods used to prevent and control a disease. **Cleanliness** provides general prophylaxis against disease, as bacteria are found in dirty, dusty conditions; cleanliness of the person, the home, and the community is necessary. **Asepsis** prevents microbes gaining access through cuts and wounds in the skin. *Antiseptics* are used for asepsis, and *disinfectants* for cleanliness; both kill microbes.

PHYSICAL VECTORS OF DISEASE

Airborne diseases. *Spitting* should be prohibited, as it deposits microbes in dust, leading to spore formation, and spread of the disease by inhaling dust. Good *ventilation* is needed to remove microbes and spores; houses should be kept clean from dust and dirt.

Water borne diseases. The microbes of these diseases are spread by bad sanitation, and contaminated water supplies. Prophylaxis needs sanitation facilities, and either ensuring a clean water supply, or filtering and boiling all water for domestic use.

Contact diseases. Prophylaxis is provided by cleanliness of the skin, and clothing. Adequate living space is needed so that there is no overcrowding, and the living quarters should be kept clean.

Food contamination. Clean hands are needed for the preparation and eating of food. All vegetables should be washed to remove dirt and bacteria. Food should be kept covered to avoid contamination by houseflies and other insects. Meat should be well cooked to kill any worm cysts. Only fresh food, certified uncontaminated, should be cooked and eaten. 'Blown' tins should be discarded.

INSECT VECTORS OF DISEASE

Prophylaxis against insects needs a study of their life cycles to determine the best methods of control.

Mosquitoes. These insects are important vectors for several diseases. *Life cycle.* Male and female mosquitoes mate, and the female lays eggs on stagnant water. The eggs of anopheline mosquitoes are laid singly, and each egg has a float on either side of the egg. The eggs hatch out and the larvae swim in the water. The larvae breathe by coming to the surface, and attaching themselves, by hairs, to the surface. Air is drawn in through two *breathing trumpets*, the larvae can only breathe in air, they drown in water. The larvae moult and grow. A pupa is formed; this is the resting stage, and a pupa breathes but does not eat. It breathes through two *breathing trumpets*.

The shapes of the larvae and pupae are shown in fig. 6.1.

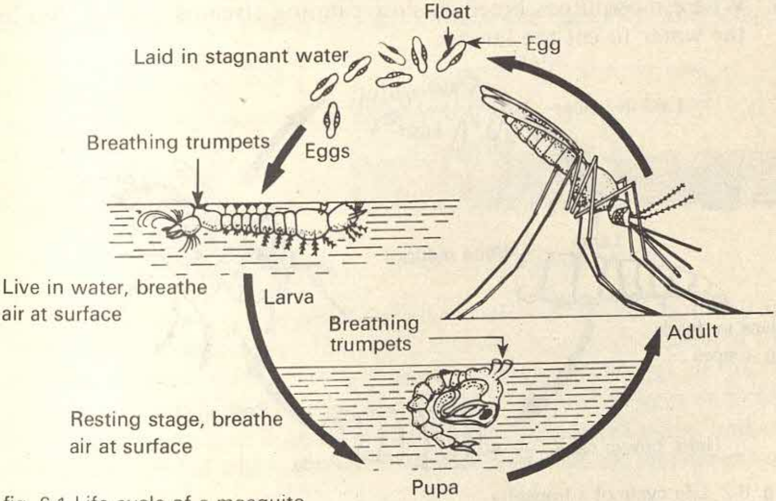


fig. 6.1 Life cycle of a mosquito

The adult mosquito develops inside the pupal case; the case splits, the adult emerges, dries its wings and flies off. Male mosquitoes suck plant juices, female mosquitoes suck blood. The female mosquito has a sharp pointed *proboscis,* which pierces the skin; saliva is injected to prevent blood clotting as it is sucked up.

Species of mosquitoes. **Anopheline** mosquitoes transmit malaria; they mainly feed on human blood. **Culecine** mosquitoes transmit *dengue fever,* a virus disease. **Aedes** mosquitoes transmit *yellow fever,* another virus disease. *Culecine* and *aedes* mosquitoes mainly feed on animal blood. All mosquitoes have the same life cycle.

Malaria prevention. Prophylaxis by drugs can be used; it is better. though, to control mosquito breeding and break the man–mosquito–man chain of infection.

Personal methods. Mosquito nets, or mosquito-proofed rooms prevent bites at night. Malaria patients *must* sleep under a net to prevent infecting mosquitoes.

Elimination of mosquitoes. These methods are based on the life cycle.

1 Residual spraying of walls with D.D.T. kills adult mosquitoes who rest in cupboards and dark places during the day.

2 Spraying oil on stagnant water. This prevents larvae and pupae breathing, as they cannot attach themselves to the water surface, and thus kills mosquitoes in the larval and pupal stages.

3 Removing all empty receptacles (tins, bottles, etc.) so that there is no stagnant water in which eggs can be laid.

4 Filling in swamps and constructing malarial drains to remove stagnant water.

5 Where mosquitoes breed in slow running streams, putting fish in the water to eat the larvae.

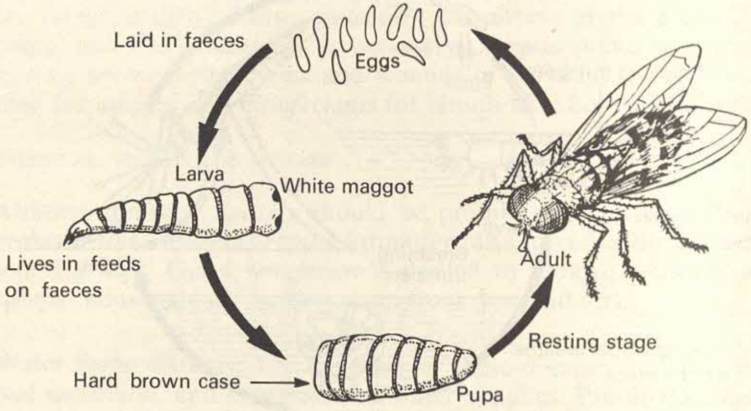


fig. 6.2 Life cycle of a housefly

Houseflies. Male and female houseflies mate, and the female lays eggs in faeces or in rotting animal or vegetable material. Eggs hatch quickly and a larva (maggot or grub) feeds on the faeces. Larvae move away from light; they grow, moult and feed for a week, then change to a pupa. The pupa is a resting stage, during which the adult housefly develops in the pupal case. The case splits, the adult housefly emerges, dries its wings, and searches for food. Its body and legs are hairy, and microbes stick readily to the legs and body. The housefly feeds on faeces, rotting foods, open sores and wounds, and on human food.

Control of houseflies. Flies are active only by day.

1 All food should be protected during storing, and preparation, and while eating it.

2 Adult houseflies should be killed by spraying *insecticides.*

3 All refuse should be burnt, so that houseflies have no suitable site for breeding.

4 Proper sanitation should be used so that flies cannot settle on faeces.

5 A well-ventilated, light and airy house attracts few houseflies.

Tsetse flies. These insects transmit sleeping sickness; the causative agent is a protozoon called a *trypanosome*. Adult flies are killed by spraying insecticides; control is difficult as the flies are parasites on game and domestic animals, as well as human beings.

Rats. Rats are actual vectors of disease but their main importance is that they act as hosts for other vectors, such as fleas, ticks, and mites. *Elimination of rats.* Elimination is the best form of prophylaxis against rat-borne diseases. Control by their natural enemies, *cats* and *ferrets,* has been used for a long time. Traps are used to catch rats, but they are intelligent and suspicious of traps. Poisoned bait is also used to kill rats. Rats are creatures of habit; they build nests, and never go too far in search of food. They are good climbers, and metal flanges on house supports are useful in keeping rats out. Rats also infest ships, and rat guards are needed when ships are in port to prevent rat movement on and off the ship.

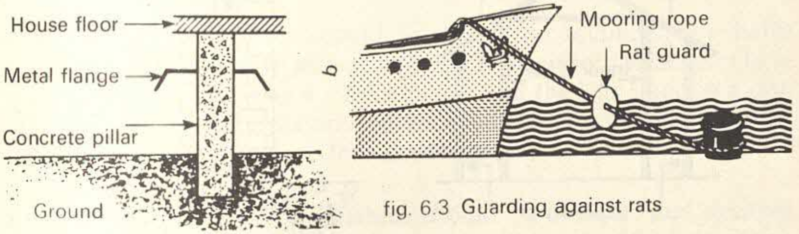


fig. 6.3 Guarding against rats

Diseases spread by rats. **Leptospirosis** is transmitted by rats' urine contaminating water supplies; the causative agent is a **spirochaete.** Fleas, ticks and mites on rats spread typhus; rat fleas transmit **plague,** the causative agent is a **bacterium.** Rat ticks transmit **relapsing fever** (causative agent is a **spirochaete**). Rats also act as hosts to many parasites such as **liver flukes**; these parasites can be transmitted to human beings.

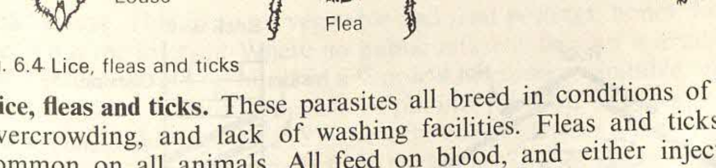


fig. 6.4 Lice, fleas and ticks

Lice, fleas and ticks. These parasites all breed in conditions of dirt, overcrowding, and lack of washing facilities. Fleas and ticks are common on all animals. All feed on blood, and either inject the microbes into the blood, or else they pass the microbes in faeces, and the microbes enter the puncture made by the parasite for its blood meal. *Control of the parasites.* Personal cleanliness and clean houses reduce the chance of infestation. Infested houses are *fumigated* and sprayed with D.D.T.

Hygiene of the home

THE HOUSE

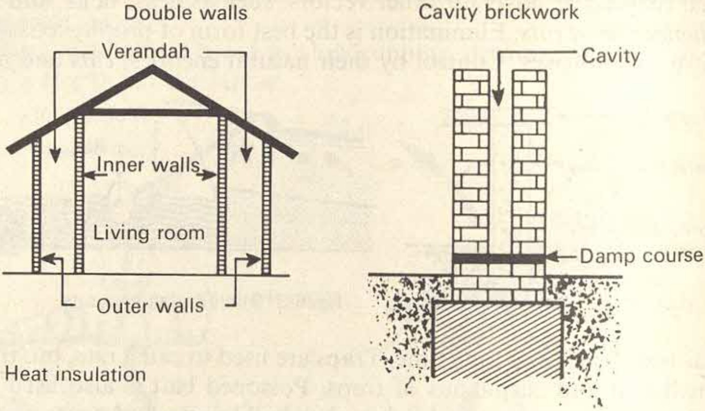


fig. 6.5 Heat insulation

Siting of the house. The best sites are on the side of a hill; the ground should be well drained. The house should be in a garden, with other houses not too close, and preferably near public services. The house should be built in an east-west direction, with windows pointing north and south, for coolness.

Design of a house. There should be at least one room for each of (a) cooking; (b) eating, living; (c) sleeping; (d) washing and sanitation. Cooking places and sanitation should be as far apart as possible. The house is kept cool by (a) using double walls, or (b) cavity brickwork (air is a bad conductor of heat). The house should be painted white, and the roof should have a ceiling beneath it.

Ventilation. Hot air rises, so cool air must be sucked in low down the wall. Air vents in the ceiling (fig. 6.6) allow hot air to escape. Ventilation bricks, placed low on the wall, allow cool fresh air to enter. A fan assists ventilation.

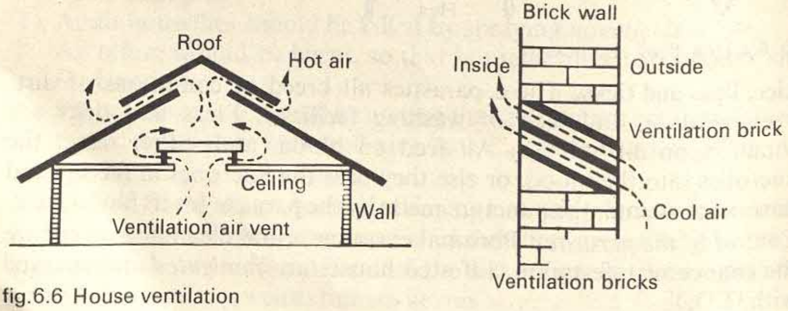


fig.6.6 House ventilation

Air conditioning. A high humidity (i.e. quantity of water vapour in the air) hinders sweating, and reduces activity. Air conditioners reduce humidity by cooling the air, removing the precipitated water, and then warming the air which is made drier.

FOOD HYGIENE

Food storage. Dry foods should be stored in containers, perishable foods should be stored in a meat safe or a refrigerator. Meat safes have wire mesh sides, allowing air to circulate, and the legs stand in a dish of water, preventing ants and cockroaches from contaminating the food. Rats are the main pests for stored food.

Preparation and eating. Vegetables should be cleaned, and decayed parts removed. All utensils must be clean, and clean hands are essential. Food should always be kept covered when it is being prepared or served, to prevent contamination by flies.

REFUSE DISPOSAL

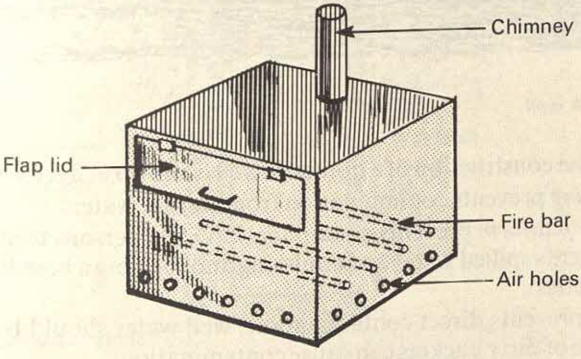


fig. 6.7 A simple incinerator

Solid refuse. This includes vegetable and fruit peelings, bones, husks, etc. from the kitchen. Where no public refuse collection is available, solid refuse should be burnt in a simple *incinerator;* a suitable type is shown in fig. 6.7. Solid refuse can be put into compost trenches, 3 feet deep, with a refuse depth of 18 inches; the compost needs 2 years before the land is usable. Waste water from the kitchen, or bathroom, is led by a pipe to a *soakage pit*. The pit is 4 feet deep by 2 feet wide, and, on average, 6 feet long, for normal household use. A layer of coarse stones covers the bottom, with fine stones above, and sand above that. The pit is covered with earth. Water filters away and refuse is digested by bacterial action, and is carried away in solution.

Where there is no public water supply, wells usually provide water.

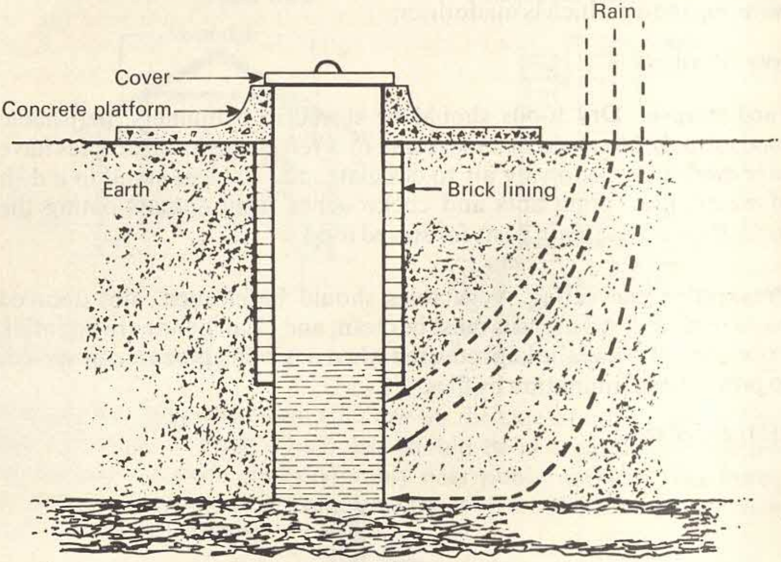


fig. 6.8 A well

Wells. The construction of a domestic well is shown in fig. 6.8.
Brick lining prevents contamination from surface water.
Concrete platform prevents contamination from persons using the well, and prevents spilled water accumulating and forming a breeding ground for microbes.
A cover prevents direct contamination; well water should be pumped, as the use of dirty buckets can cause contamination.

Siting of wells. Wells should be dug uphill from latrines, soakage pits, and cesspools, and at least 100 feet from the nearest latrine. *Polluted water* may contain excreta, sediment, or plant growths. **Filtration** is necessary for all domestic water, other than piped supplies. If disease is prevalent, domestic water should be boiled for 20 minutes before use.

Types of well. *Surface wells* obtain their water from rain draining through the soil (fig. 6.8). A *non-porous* layer of clay prevents further drainage of water. *Deep wells* pass through non-porous layers, and tap water beneath; water from these wells is purer. *Artesian wells* are only found in special rock formations where underground water is under pressure.

DOMESTIC SANITATION

Pit latrines. The construction of a latrine is shown in fig. 6.9. Houseflies rarely live in holes deeper than 10 feet, and so will not feed on the faeces.

rarely live in holes deeper than 10 feet, and so will not feed on the

faeces. The earth is *porous* to allow liquid *excrement* to drain away. Bacteria digest the faeces, making it harmless, but 100 feet is a necessary drainage distance to ensure safety. The pit is covered with a concrete platform, and a lid used to discourage houseflies; a shelter should be provided. The platform should be disinfected with chloride of lime; no disinfectants should be allowed into the pit, otherwise bacterial decomposition is stopped.

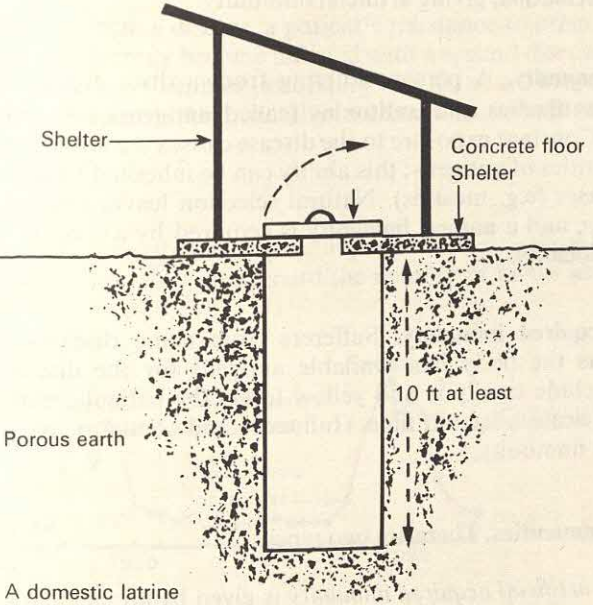


fig. 6.9 A domestic latrine

Bore-hole latrines. A hole is bored, by an *auger*, to a depth of 20 feet, with a diameter of 1 foot. Protection is the same as for pit latrines. Bore-hole latrines can be used for a longer period of time, and need not be filled in, as are pit latrines, as the contents are digested and drained away.

DOMESTIC HYGIENE

The basis of good domestic hygiene is the safe disposal of urine and faeces, together with a clean water supply. Precautions taken with food, together with good sanitation and clean water, ensure that no diseases are transmitted. Cool, clean, airy houses keep down insect pests, and avoid microbes in dust. Domestic hygiene is the practice of all these precautions.

Defence against disease

IMMUNITY

Historical introduction. Jenner, an English doctor, was the first person to conquer disease by giving immunity. He noticed that **cow-pox**, a disease caught from cows, gave immunity to **smallpox**. To test this theory, he *inoculated* a boy with pus taken from the nodules of a sufferer from cow-pox. Two months later, he inoculated the same boy with pus taken from a sufferer from smallpox. The boy did not fall ill with smallpox, he had acquired immunity against the disease. Jenner had discovered **vaccination,** giving artificial immunity.

Natural immunity. A person suffering from a disease (e.g. measles) produces **antibodies** and **antitoxins** (called **antigens**) to combat the microbes. Constant exposure to the disease causes the body to produce large quantities of antigens; this ability can be inherited by children for some diseases (e.g. measles). Natural selection leaves survivors who are *immune*, and a **natural immunity** is acquired by a race, or people, living in a locality.

Natural acquired immunity. Sufferers from some diseases become immune, as the body has available antigens for the disease. Such diseases include smallpox and yellow fever; the patient cannot suffer from the disease a second time. (Influenza and common colds form a short-lived immunity.)

Artificial immunities. There are two types.

1 *Active artificial acquired immunity* is given by an inoculation with a **vaccine.** The vaccine contains either (a) killed bacteria or (b) a mild strain of bacteria. On inoculation, the person does not suffer from the disease, but the body cells produce antigens, and prevent him from being seriously ill from an infection of the disease.

2 *Passive artificial acquired immunity* is given by **sera**. A **serum** contains antibodies and antitoxins. An animal is injected with the disease; its blood is drawn off and clotted; the clear liquid remaining is a serum. A serum provides the body with its antigens already formed; a vaccine stimulates the body to form antigens. Sera can be injected into patients already suffering from a disease, but vaccines cannot. Sera help the patient to overcome the disease and acquire an active immunity.

ANAEMIA

A person is *anaemic* when there are too few red corpuscles in his blood. The lack of red corpuscles hinders the transport of oxygen to the body cells, and insufficient energy is released in respiration. Anaemia causes paleness and weakness; sufferers are more liable to infection. The chief causes of anaemia are *malaria*, *hookworm*, and *malnutrition*. Lack of protein, and vitamin B complex affect the assimilation of iron salts, resulting in fewer red corpuscles. *Iron tonics* are administered in most cases of recovery from illness to overcome the liability to anaemia.

SECONDARY INFECTIONS

After suffering from a disease, a patient's resistance to other microbes is lowered, and he may become infected with a second disease, called a **secondary infection**. Common secondary infections are bronchitis and pneumonia. Proper nursing, usually in a hospital, is needed to avoid such infections.

Medical statistics

Medical statistics record the number of people suffering from the major diseases every year; they also record the number of births and deaths.

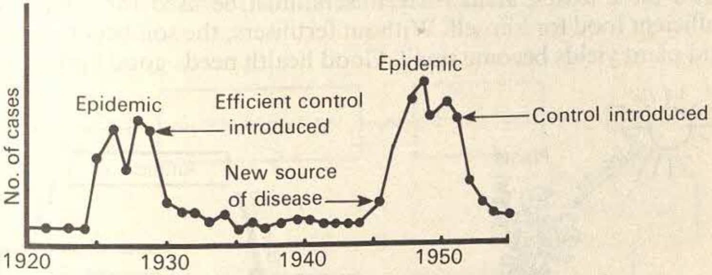


fig. 6.10a The history of a disease

Statistics are usually compiled in graphical form (fig. 6.10a); this shows the course of a disease and whether the treatment being given is generally effective or not. An epidemic is shown by a peak in the graph, and the effectiveness of treatment by the reduction in the number of people suffering from the disease. Statistics can also be useful in tracing the cause of a disease. Fig. 6.10b indicates how this can be done. Two species of mosquitoes (A and B) are suspected of being the cause of malaria. Routine catches of mosquitoes are made, and a graph drawn of the number caught. A graph is also drawn for the number of people admitted to hospital suffering from malaria. The graphs show that the annual rise and fall in malaria follows the same cycle as the number of mosquitoes of species A; these are the most likely vector of the disease.

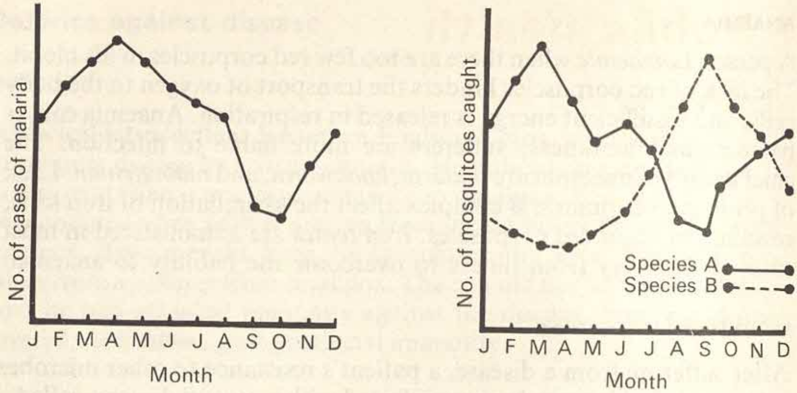


fig. 6.10b The cause of a disease

Food and survival

The important foods containing starch and protein take part in the natural carbon and nitrogen cycles (fig. 6.11 and 6.12). The mineral salts used by plants and animals follow similar cycles. Man breaks these cycles by not returning the chemical elements to the ground. The loss through the disposal of urine and faeces is the most important. To make good these losses, artificial fertilisers must be used for man to grow sufficient food for himself. Without fertilisers, the soil becomes poorer, and plant yields become small. Good health needs good agriculture.

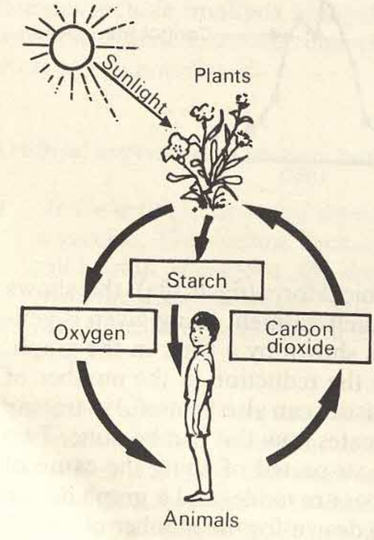


fig. 6.11 The carbon cycle

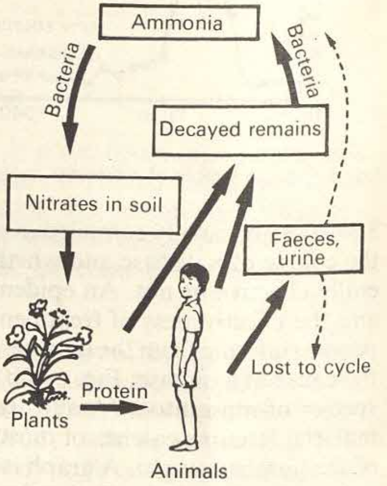


fig. 6.12 The nitrogen cycle

7 Public health

Public services

In urban communities, hygiene of the home cannot be practised as described, so public authorities supply services to maintain health. Public health authorities should (a) ensure proper sanitation (b) supply clean water (c) collect refuse and clean streets, and (d) prevent the spread of disease and offer medical assistance to cure disease. In villages, a Sanitary Board organizes health services; in towns a Public Health Authority; both make by laws for their own conditions. A country has a Ministry of Health that makes laws to ensure the health of the inhabitants.

Water supplies

Piped supplies. Water is obtained from a lake or a reservoir (i.e. an artificial lake). Water from the reservoir is purified in a *waterworks*, and then passes through a *pumping station* to a *service reservoir*, which is usually a very large concrete tank. The service reservoir is placed on a hill, so that the water pressure forces water out of taps in houses, which are at a lower level than the service reservoir.

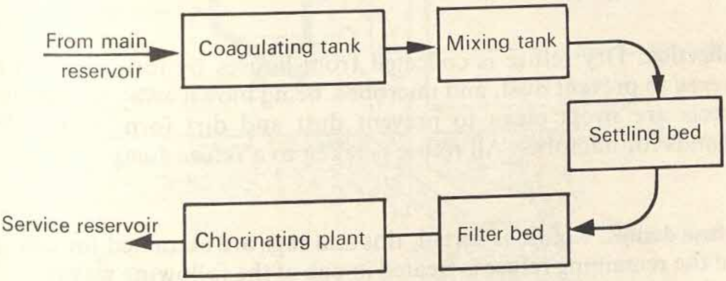


fig. 7.1a Plan of waterworks

A waterworks. Water in the storge reservoir contains mud, suspended sediment, and probably some bacteria; sunlight on the water kills bacteria, while the water is in the reservoir. The waterworks removes suspended particles and bacteria (fig. 7.1a). In the first tank of the waterworks, *lime* and *aluminium sulphate* are added; these *coagulate* fine particles of sediment into larger particles; this action takes place in the *mixing tank*. The water enters the *settling bed*, where all but the very fine particles are deposited as sediment. The *filter bed* is the most important part of the works; in it, all particles and most bacteria are filtered off. The construction is shown in fig. 7.1b, with layers of sand and stones. The last tank in the waterworks is the *chlorinating plant*, where chlorine is added to kill remaining bacteria.

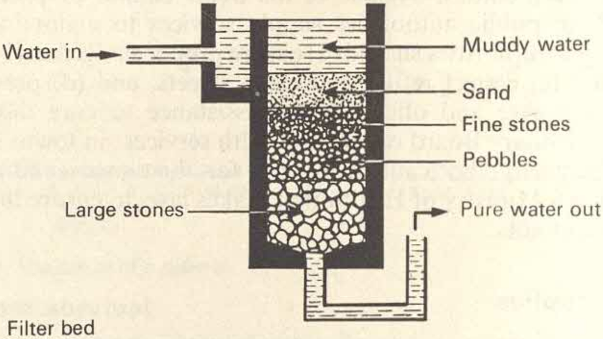


fig. 7.1b Filter bed

The filter bed. Small plants grow on the sand, forming a *slime* on the surface. These plant bodies feed on bacteria and form the true filter. A filter bed with a growth of slime is called a 'ripe' bed. Only 'ripe' filter beds can be used. Water delivered by pipes is thus clear, and uncontaminated by bacteria.

Refuse disposal

Collection. Dry refuse is collected from houses by lorries which are *covered* to prevent dust, and microbes, being blown away by the wind. Streets are swept clean to prevent dust and dirt forming breeding grounds for microbes. All refuse is taken to a **refuse dump**.

Refuse dumps. Refuse is sorted, tins and rags are extracted for salvage, and the remaining refuse is treated in one of the following ways:

1. *Incineration*. Refuse is burnt in large furnace with a tile chimney; it produces cinders and clinker. These can be used to make roads, or bricks for building. Incineration is the best method of refuse disposal.
2. *Controlled dumping*. Refuse is dumped on waste land, e.g. swamps to be filled in, or valleys to be levelled off. The refuse is covered immediately with earth to prevent rats breeding. After settling for a long period, the land can be used.
3. *Disposal at sea*. Refuse is taken out by barge and dumped at sea (useful only for coastal towns).
4. *Composting*. Refuse is put in trenches, covered with earth, and allowed to rot; this can only be used for vegetable refuse.

Sewage disposal

Communities with a piped water supply use water closets for sewage disposal. The sewage from the closet is water-borne, and in rural areas is disposed of in a septic tank, and in urban areas by a sewage works.

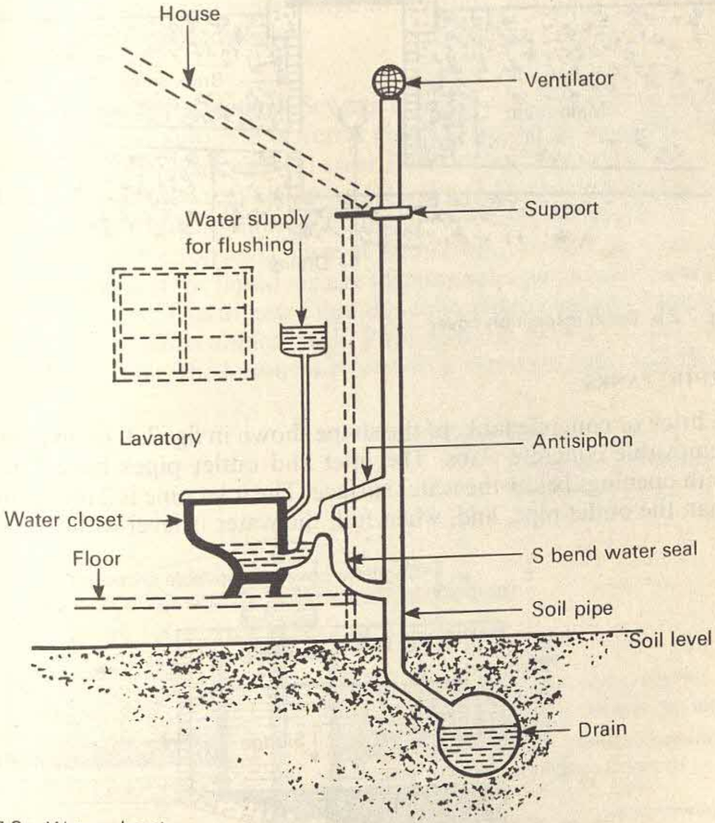


fig. 7.2a Water closet

Water closets. A flush lavatory is shown in fig. 7.2a. A tank is used to flush the pan with water; *an S-shaped bend* provides a water seal, to prevent gases from decomposing sewage entering the house. The pan is joined to a *soil-pipe*, connecting to the *drain*. An antisiphon pipe is used if two or more flush lavatories join the same soil-pipe; this prevents water being sucked out of the water seal. A *ventilator*, at the top of the soil-pipe, ventilates the drains; it is protected by wire netting to prevent leaves, etc. entering and blocking the drain. *Drains* are made of glazed stoneware and are round, they lead into *inspection chambers*; there are no sharp bends in drains, as this avoids blockage. The *inspection chamber* is brick-lined, covered with an airtight iron cover, and is the meeting point of two or more drains. From it the main drain connects to a septic tank or a sewer.

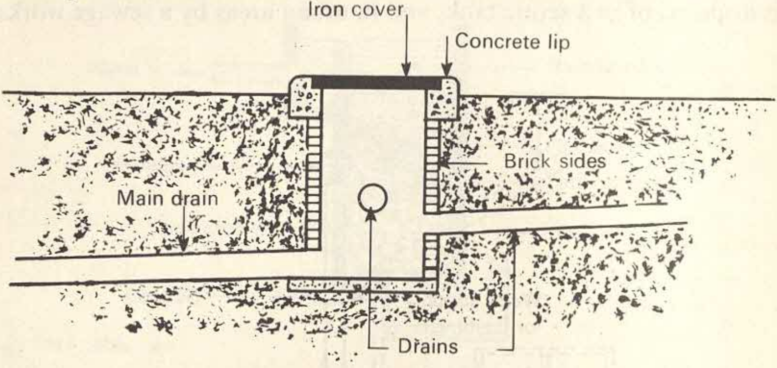


fig. 7.2 b Drain inspection cover

SEPTIC TANKS

A brick or concrete tank, of the shape shown in fig. 7.3, is covered with removable concrete slabs. The inlet and outlet pipes have T-pieces, with openings below the water surface. The inlet pipe is 2 inches higher than the outlet pipe, and, when full, the water is level with the outlet.

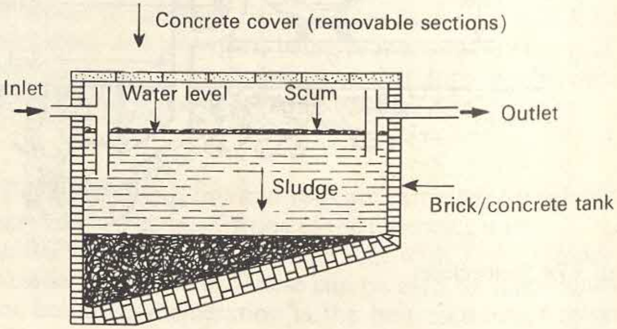


fig. 7.3 A septic tank

Anaerobic bacteria form a scum on the surface, and decompose solid faeces. During digestion, heavy **sludge** is formed, which sinks to the bottom and continues to decompose. The liquid products of decomposition leave by the outlet pipe to a soakage pit (p.89), where decomposition is finished by aerobic bacteria. Sludge is pumped out of the septic tank once every 1 – 3 years, but some must be left to continue bacterial activity.

Sewers are brick-lined and egg-shaped to allow a free flow of sewage under gravity. Too slow a flow deposits sediment. Ventilators are needed to prevent blow-outs of sewage traps in inspection covers. *Raw sewage* from sewers reaches sewage works and first passes through 'grit channels' to remove grit and dirt; it then passes through a *disintegrator* to remove any large indigestible solids. It is then treated by either of the two methods below.

1 **The biological filter method.** Sewage is put in a *sedimentation tank*, and aluminium sulphate or ferric chloride added to coagulate it. This forms (a) *sludge* and (b) *clear liquid sewage*.

   The liquid is passed to a *biological filter* (fig. 7.4); the *rotating distributor* sprinkles the liquid into a circular tank containing clinker or stones, fine at the top and coarse at the bottom. *Aerobic bacteria* on the clinker digest the liquid sewage forming solid particles of humus and clear water. This digested liquid is collected in outflow channels and led to a *sedimentation tank*. Pure water is drawn off and returned to a river, the humus is passed to a digestion tank, together with the sludge (a) above. The digestion tank (fig. 7.5) forms *digested sludge by* the action of *anaerobic bacteria*; excretory products are *methane* and *carbon dioxide*. The methane is burnt to warm heating coils in the tank. The temperature in the tank is kept at 95°C. to speed the reaction. Digested sludge collects in a pit, and is drawn off, periodically, through a pipe; it is placed in *drying beds*, and when dry is used as a fertiliser.

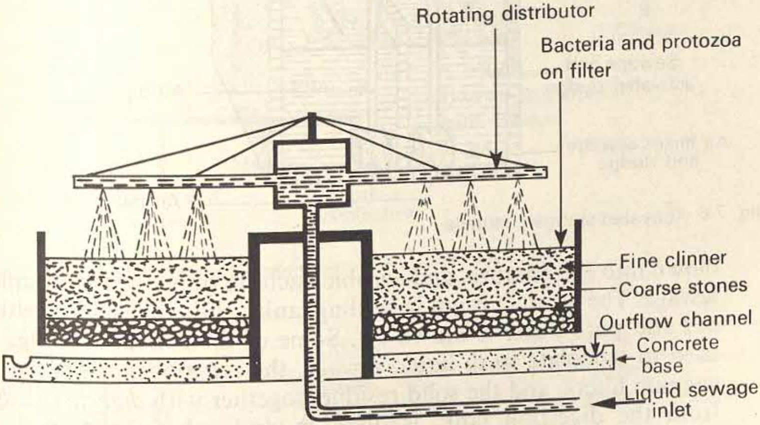


fig. 7.4 A biological trickling filter

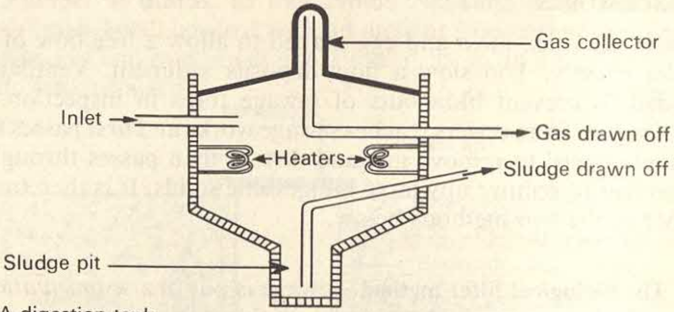


fig. 7.5 A digestion tank

2 **The activated sludge method.** Sewage is put in a *sedimentation tank* and treated as above (1). Solids are digested in a digestion tank (as in method 1); liquid sewage is put in *activated sludge channels* (fig. 7.6) and inoculated with biologically activated sludge. Air is blown into the mixture, and aerobic bacteria fully digest the liquid sewage. The product is put in settling tanks, activated sludge settles out and pure water is drawn off. Some of the activated sludge is used to inoculate fresh liquid sewage, the remainder is filtered in vacuum filters, and the solid residue, together with *digested sludge* from the digestion tank, is dried in *drying beds*, and used as fertiliser.

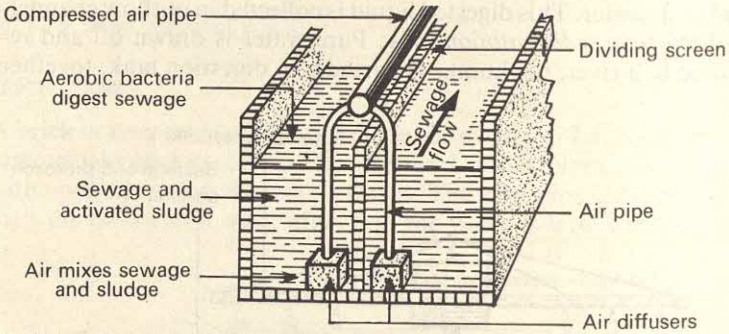

Compressed air pipe
Dividing screen
Aerobic bacteria digest sewage
Sewage flow
Sewage and activated sludge
Air pipe
Air mixes sewage and sludge
Air diffusers

fig. 7.6 Activated sludge channels

Food hygiene

Production. Meat from animals killed in slaughter houses has to be passed fit for consumption (see contamination of food and worms, p. 65). Canned foods are allowed to have preservatives added; the kinds of preservative, and the amounts added, are controlled by law. **Public Analysts** test samples taken by **Food Inspectors**. *Adulteration* of food is a serious offence.

Distribution and storage. The *Pest Control* section of the Public Health department destroys rats and other food pests. Food inspectors ensure transport and storage is carried out under hygienic conditions. Restaurants and eating shops are regularly inspected to ensure people associated with the preparation and sale of food are free from disease.

Health officials

The Medical Officer for Health (M.O.H.)

The more important duties of a Medical Officer for Health are shown in fig. 7.7. His first responsibility is the control of diseases of an infectious nature, and the various departments assist in this.

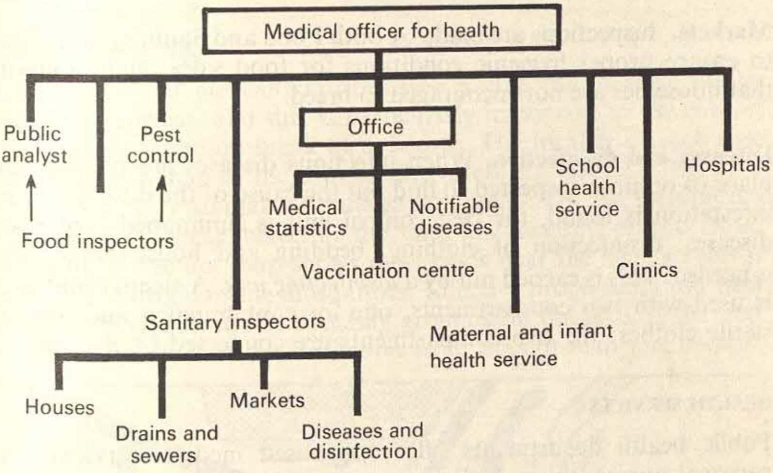


fig. 7.7 A Public Health Department

Notifiable diseases

Smallpox
typhoid fever
scarlet fever
erisypelas
cholera
plague
relapsing fever
typhus
diphtheria
puerperal fever

Any doctor must notify the occurrence of these diseases and the location of the patient to the health authority; they are all severe diseases which can lead to epidemics. The M.O.H. must take steps to confine the disease.

Vaccination centre. Vaccines against smallpox, tetanus, yellow fever, plague, cholera and typhoid are always available. Vaccine and sera can also be given for rabies, typhus, diphtheria, etc., if the need arises.

SANITARY INSPECTORS

These officials are responsible for seeing that general health rules are obeyed by the community.

Houses. Inspection shows whether houses conform to building standards, whether houses are overcrowded or dirty, and whether refuse is properly disposed of, whether drains are in order, and mosquito breeding grounds are kept clean.

Drains and sewers. These are inspected regularly for leakages and stoppages.

Markets. Inspections are made by both Food and Sanitary Inspectors to ensure proper hygienic conditions for food sales, and to ensure that houseflies are not encouraged to breed.

Diseases and disinfection. When infectious diseases are notified, the place of origin is inspected to find out the cause of the disease. If pest infestation is found, the pest control unit is summoned. For some diseases, disinfection of clothing, bedding and household articles is needed. This is carried out by a *disinfecting unit*. A steam disinfector is used with two compartments, one for contaminated and one for sterile clothes; the two compartments are connected by a trolley.

HEALTH SERVICES

Public health departments offer specialised medical services, and personal services through clinics.

Maternal and infant health. These offer pre-natal (i.e. before birth) and post-natal (i.e. after birth) care; such care is important as many infants die in the first year of their life.

School health services. Good health is important if children are to benefit from education; the large number of children in a school offers a potential danger for an epidemic. For both reasons pupils are regularly inspected, and vaccinated against possible diseases. The hygiene of the school is also inspected. A dental service is usually provided as well, as care taken of the children's teeth results in better teeth when they are adults.

Clinics. Mobile clinics in rural areas, and clinics for out-patients in hospitals, provide general medical attention for the public.

Hospitals. There are general and specialist hospitals. A *general hospital* treats medical and surgical cases, and separate blocks of wards are available for each. The *operating theatre* is near the surgical wards. Each ward in the medical block is for nursing a different type of disease (e.g. malarial fevers; intestinal diseases; skin diseases). The out-patients' clinic treats and admits patients. A special *isolation ward* is provided for severely infectious diseases. A *maternity ward* and clinic are separate from the other buildings to avoid the spread of infection. An administration block houses offices and medical records; a kitchen and staff quarters provide domestic services, and there is also an ambulance park and a mortuary. *Specialist hospitals* are provided for tuberculosis; certain infectious fevers; maternity cases.

MEDICAL STATISTICS

Besides the usual medical statistics (see p. 83), the location of the patient is recorded, and this is particularly important in the case of an epidemic, or the outbreak of a disease. The locality of each case is marked on a map of the district; the result is a dot map (fig. 7.8). In this case, an outbreak of malaria is studied. Do the mosquitoes causing the outbreak breed in the lake, the swamp, or the river? Inspection of the dot map shows most cases near the lake, so this is the probable origin of the mosquitoes. Effective prophylaxis will then be taken against mosquito breeding grounds on the lake. If the outbreak dies down, then the deduction from the dot map was correct.

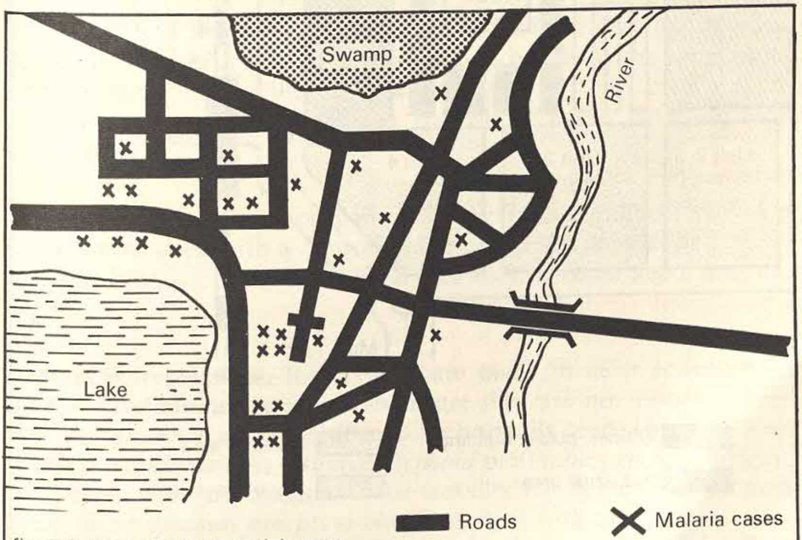


fig. 7.8 Dot map for malarial cases

Town planning

TOWN PLANNING DEPARTMENT

This is usually a section of the Public Works department; it supervises housing schemes in connection with the health authorities. The town plan in fig. 7.9 illustrates the following necessities of good planning.

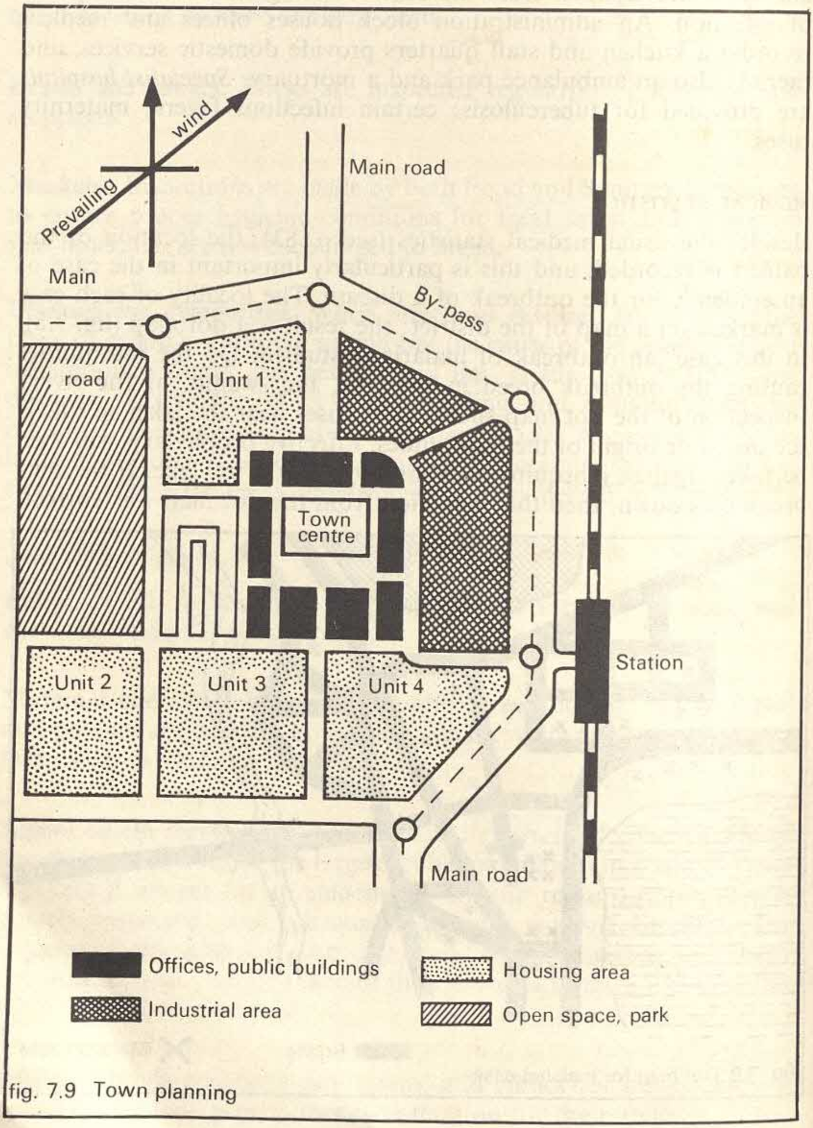


fig. 7.9 Town planning

1 Zoning. The town is divided into zones for different forms of community life. Only simple zones are given in the plan.

2 Roads. Main roads should not run through towns, as heavy traffic fouls the air; a by-pass road is provided round the town, and it gives easy access to all parts of the town. There should be no direct route by minor roads straight through the town.

3 Industrial zone. This is placed so that smoke and fumes are not blown over the town by the prevailing wind.

4 Open spaces. Parks and sports grounds are provided for the town, so that the prevailing wind does not blow from the town over the open space.

General points

1 Houses should be properly spaced to prevent overcrowding.
2 Each zone must have an adequate water supply and sewage system.
3 Each living unit should provide basic necessities, e.g. a school, general shops, green spaces.

International health control

Descriptions of diseases. Regulations are made to describe diseases. *Epidemic diseases* spread and attack many people at the same time; they are restricted to a locality or a country.
Pandemic diseases spread across the whole world (a world-wide epidemic).

Endemic diseases are always present in certain localities; they are usually associated with a natural immunity of the population.
Sporadic diseases occur in isolated localities, become acute and die down.

Quarantine regulations. Regulations are made in most countries to isolate travellers in **quarantine** to ensure they are not sources of infection. Valid vaccination certificates are normally needed by travellers; *smallpox* vaccination is essential; *typhoid* preferable; *cholera, plague*, and *yellow fever* are essential if the traveller has come from an area where these diseases are prevalent. Countries with airports and seaports are required to notify immediately the presence of **pestilent diseases**: *smallpox, cholera, plague, yellow fever, typhus.*

The organisation is shown in fig. 7.10. The 11 headquarter sections are: notification and control of infectious diseases; maternal and child welfare; dietetics; mental health; health research; standardisation of drugs; quarantine regulations; sanitation and water supplies; health education and training; health statistics; publications. The 6 regions are: the Americas; Europe; Eastern Mediterranean; Africa; South East Asia; Western Pacific. Each area has its own special health problems.

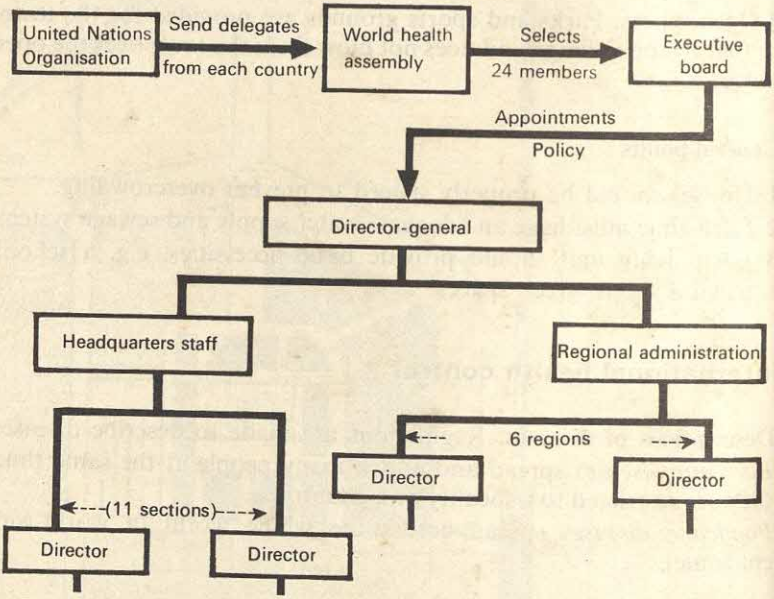


fig. 7.10 The World Health Organisation

Work of W.H.O. The organisation sends out information to all member countries. It particularly assists in controlling the international spread of diseases by its warning system. Help is given to underdeveloped countries to raise their standards of health control. Assistance is given on specific problems such as radiation hazards from X-rays and atomic energy plants; malaria control campaigns in some countries; help with problems of diets; training facilities for underdeveloped countries.

Longman